MASTER'S THESIS M-1373

BOS, Gregory Neil
RANGE TYPES AND THEIR UTILIZATION BY MUSKOX ON NUNIVAK ISLAND, ALASKA: A RECONNAISSANCE STUDY.

University of Alaska, M.S., 1967
Agriculture, forestry and wildlife

University Microfilms, Inc., Ann Arbor, Michigan

RANGE TYPES AND THEIR UTILIZATION BY MUSKOX

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A

THESIS

Presented to the Faculty of the

University of Alaska in Partial Fulfillment

of the Requirements

for the Degree of

MASTER OF SCIENCE

By

Gregory Neil Bos, B. S.

College, Alaska

May, 1967

RANGE TYPES AND THEIR UTILIZATION BY MUSKOX

ON NUNIVAK ISLAND, ALASKA: A RECONNAISSANCE STUDY

APPROVED:

Frederick C. Dean

Chairman

Frederick C. Dean

Department Head

APPROVED: Bruna Kessel

Dean of the College of Biological Sciences and Renewable Resources

DATE: 12 May 1967

Vice President for Research and Advanced Study

ABSTRACT

Population history and range interrelationships were studied in 1965 and 1966 in a reconnaissance study of the Nunivak Island muskox. Range types on the island were described in terms of dominant cover species, and their distribution was mapped. Wet tundra is the most extensive type, covering about 57.5% of the island. The other types and the areas they cover are the grass-browse, 23.4%, the dry tundra, 14.2%, the beach grass-forb, 0.4%, the barren rock, 2.5%, and the aquatic, 2.0%.

The muskox population has grown from the 1936 introduction of 31 animals to an estimated 620 animals in 1966. Loss on winter ice is suspected to be the major mortality factor. Nunivak muskox cows calve in successive years, and a natal sex ratio of 3:1 in favor of males is indicated. The average summer herd size was 8, while in winter it was 11. Composition counts from 1966 indicate calves formed 21% of the population, while yearlings formed 17%, subadults 10%, and adult cows 25%. In summer, 8% of the population is solitary bulls. The 1966 calf:adult cow ratio was 85:100.

Muskox concentrate on a narrow coastal fringe during winter. In summer, the herds disperse widely over the tundra. Primary winter use is restricted to the beach grass-forb and wet tundra types, while in summer the grass-browse type is used. Presently, there is little competition between reindeer and muskox on winter ranges. Reindeer were introduced to the island during the 1920's, increased rapidly in numbers, and experienced wide population fluctuations. The 1966 estimate of the reindeer population was 8,000. The reindeer range was largely overgrazed by the mid-1940's and remains in poor condition today.

ACKNOWLEDGMENTS

This study was supported by funds from Federal Aid to Wildlife Restoration, Alaska Projects W-15-R-1 and W-15-R-2, through the Alaska Cooperative Wildlife Research Unit. Many individuals and organizations assisted in various aspects of the study, but I am particularly indebted to the following people:

Dr. David R. Klein, Leader, Alaska Cooperative Wildlife Research Unit, for initiation of, and assistance throughout, the study; and for his many suggestions and helpful criticisms during the preparation of the manuscript.

Dr. Frederick C. Dean, University of Alaska, for helpful suggestions regarding the study and for critical reading of the manuscript.

Dr. R. D. Guthrie, University of Alaska, for critical reading of the manuscript.

The U.S. Bureau of Indian Affairs for provision of facilities at Mekoryuk, and especially to Mr. Lee Ellis and Dr. Fred Honsinger of that organization, who provided assistance and warm hospitality during my stay on Nunivak Island.

Mr. Howard Bowman, U.S. Fish and Wildlife Service, an excellent pilot and friend, whose logistic support in the field deserves special thanks.

Mr. David L. Spencer, Refuge Supervisor for Alaska, U.S. Fish and Wildlife Service, for making possible my participation in the muskox aerial surveys.

Personnel of the Clarence Rhode National Wildlife Range for assistance and support at Bethel as well as on Nunivak Island. I am especially indebted to Dr. Calvin J. Lensink, manager, for his unlimited hospitality and valued assistance.

Messrs. Joe Hoare and Henry Condon, U.S. Geological Survey, for their assistance in transportation on the island and for enlightening conversations on Nunivak geology.

The U.S. Geological Survey offices at the University of Alaska and in Fairbanks for use of their reduction equipment.

Mr. Henry Ivanoff, who acted as my able guide and assistant during the 1966 field season.

Last but not least, to my mother, Mildred V. Bos, for accomplishing the burdonsome task of typing the final draft of the thesis.

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INTRODUCTION

The muskox (Ovibos moschatus), once native to Alaska's artic slope, was extirpated from Alaska in the latter half of the 19th century. The species was reestablished in the state in 1935 and 1936 when 31 Greenland muskox were introduced to Nunivak Island, a national wildlife refuge. Following slow initial increases, the population soon achieved a substantial growth rate, growing to more than 600 animals by 1966.

Among the objectives of the Nunivak introduction were the possibilities of future transplants to former ranges in Alaska and agricultural and recreational utilization of the muskox. Disposition of the resource was to follow attainment of an arbitrary population level of about 500 muskox. That level was being approached in 1965 when this study was initiated by the Alaska Cooperative Wildlife Research Unit.

The investigation was of a reconnaissance nature, with objectives of determining the basic population dynamics and range interrelationships of the muskox. Available past records of the population, sex and age composition counts, and general field observations were used to determine characteristics of the Nunivak muskox. The problem of defining basic range relationships of the muskox population was approached from a broad perspective with emphasis on describing the components of the Nunivak range. The presence on the island of the largest single reindeer herd in Alaska complicated the problem. Muskox-reindeer interrelationships were superficially determined since a large number of unknown variables were involved. The study, however, serves to point out some of the aspects which require attention if an understanding of the situation is to be gained.

THE STUDY AREA

Nunivak Island is located in the Bering Sea off the western coast of Alaska, between 166° 30' W and 168° 30' W longitude and between 59° 45' N and 60° 30' N latitude. It is separated from the mainland, 20 miles away, by Etolin Strait and is 145 airline miles west-southwest of Bethel, Alaska.

The climate of Nunivak Island reflects the influence of the surrounding sea (Table 1). The temperature regime is relatively stable, particularly during the time the sea is not frozen. The average annual temperature is 29° F and the average annual rainfall is 16 inches. The growing season (frost-free period) is 105 days.

GEOLOGY.

The island is approximately 70 miles long and about 50 miles wide, constituting an area of about 1,700 square miles or 1,109,400 acres (Fig. 1). The topography is relatively featureless except for the mountains and volcanic cones of the interior. The west coast of the island from Nash Harbor on the north to the Binajoaksmiut River on the south consists of sea bluffs several hundred feet high. From the Binajoaksmiut River east to Cape Corwin the coast is low with extensive sand dunes. The comparatively low north and east coasts are predominantly underlain by basalt. One small portion of the coast at Cape Manning is being eroded by sea wave action. Inland from the coast the land rises gradually to interior uplands of about 500 to 800 ft elevation. The highest point on the island is Roberts Mountain, with an elevation of 1,675 ft.

Table 1. Climatological data for Nunivak Island, Alaska. (U.S. Weather Bureau, Anchorage, Alaska)*

Month	J	F	M	A	M	J	J	A	S	O	N	D	
Temperature (°F)													Mean
Daily maximum	17.1	17.4	21.1	27.6	38.8	49.6	54.5	54.6	49.5	39.8	29.9	19.6	34.3
Daily minimum	3.8	3.7	7.3	17.0	28.9	37.5	43.4	45.2	41.1	30.5	20.2	7.6	23.7
Monthly mean	10.5	10.5	14.2	22.8	33.9	43.6	48.9	49.9	45.3	35.2	25.1	13.6	29.0
Precipitation (inches)													Total
Mean rainfall	0.84	1.90	1.17	0.70	0.59	0.77	1.25	2.34	2.07	2.01	1.34	1.02	16.00
Mean snow and sleet	10.6	9.1	9.5	4.5	2.6	T**	0.0	0.0	T	2.2	7.0	8.9	54.4

* Based on an 18-19 year summary.

** Trace, an amount too small to measure.

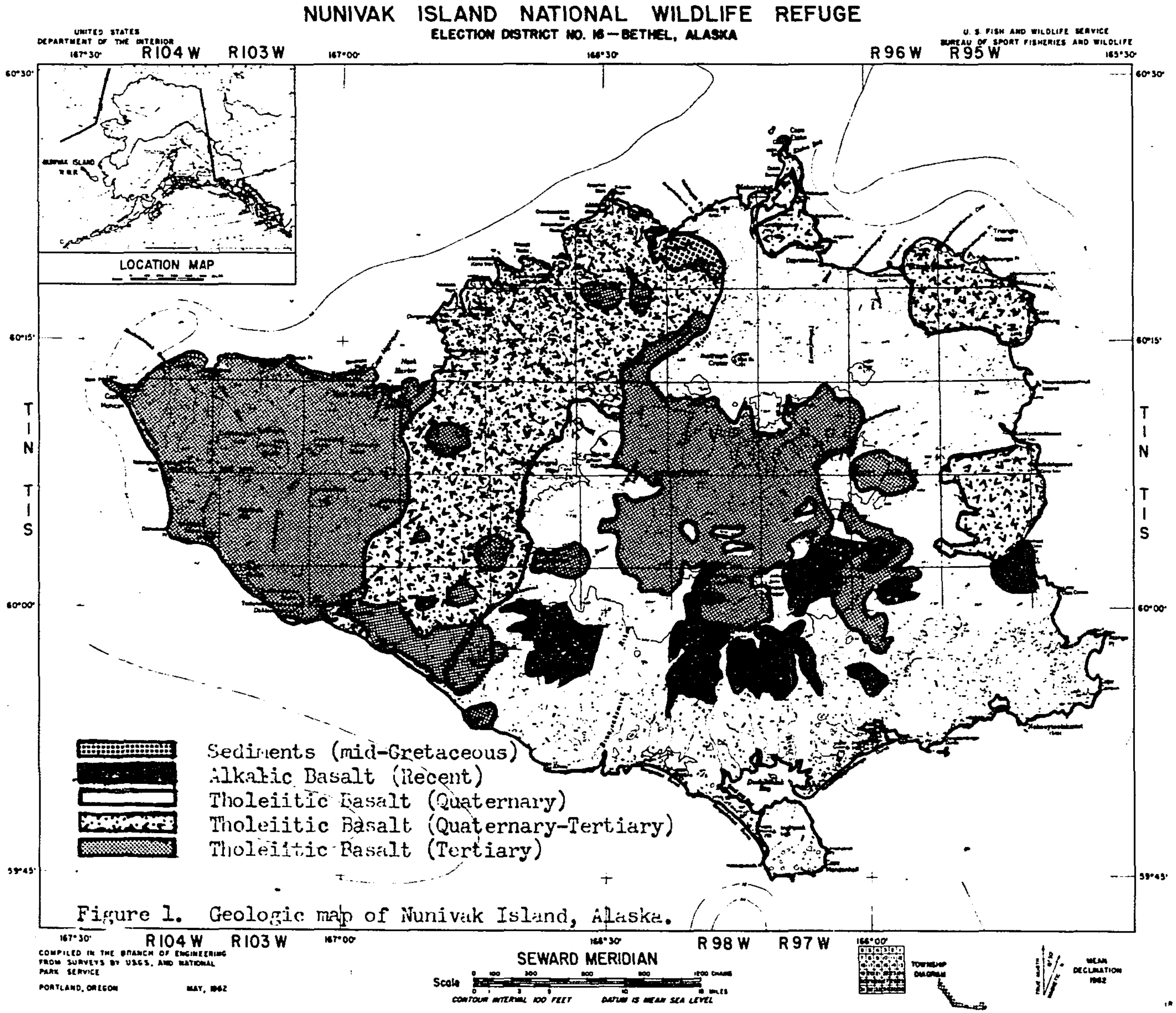

Figure 1. Geologic map of Nunivak Island, Alaska.

Numerous lakes and ponds are present on the low, marshy terrain, and several small lakes occupy old eruption craters. Stream patterns are dendritic. Upper portions of many of the streams which originate in the interior uplands are seasonal, becoming dry by July. Small closed drainage systems are present in sink areas.

The geological history of the island is currently under study by the U.S. Geological Survey (U.S.G.S.). The following geological description is based in large part on findings of Hoare and Condon (1965, verbal communication).

The island is almost entirely volcanic. Two locations, one at Nash Harbor and one in the Iookswarat Bay - Ingriruk Hills region, are sedimentary in origin, consisting of interbedded non-marine sandstone, conglomerate, and shale of mid-Cretaceous age. Recent and contemporary beach and dune sand deposits are present on the southern coast. The remainder of the island is volcanic and consists of alkalic and tholeiitic basalts. There are many cinder cones and alkalic basalt flows in the southern interior. The cones and flows range in age from a few hundred to probably several thousand years. Craters are of an intermediate age. Young lava flows still have a rough barren surface. The major portion of the island is made up of many large sheets of tholeiitic basalt which were probably derived from numerous large vents presently represented by broadly rounded mesa-like high points. These basalts are much older than the alkalic rocks, probably early Pleistocene to Pliocene age.

The oldest lava flows, of Tertiary age, are found in the interior of the island and on the western tip, west of Nash Harbor. The next oldest flows occur in the area bounded on the north by the coast between Nash Harbor and Iookswarat Bay and on the south by the coast between the Kiyakyaliksamiut River and the Chakwakamiut River. There are also isolated flows north of Twin Mountain and in the Cape Manning region. The most recent tholeiitic flows, of Quaternary age, are found on the southern side, extending northward in a ring around the older interior (Fig. 1).

FLORA AND FAUNA.

The flora of Nunivak Island will be treated in detail in the section on range. For the most part, the vegetation is of the dwarf arctic tundra form. There are no trees on the island. Willows up to 8 ft high are the tallest vegetation.

The terrestrial fauna includes muskox (_Ovibos moschatus_)[1], reindeer (_Rangifer tarandus sibiricus_), arctic fox (_Alopex lagopus_), red fox (_Vulpes fulva_), mink (_Mustela vison_), least weasel (_Mustela rixosa_), and some cricetids and soricids. Caribou (_Rangifer tarandus stonei_) were once present on the island, but they were extirpated before the turn of the century, probably as a result of overhunting. Wolves (_Canis lupus_) also occurred on the island but disappeared after the caribou were gone.

Marine mammals are present during most of the year. Walrus

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[1]The scientific names are from Hall and Kelson (1959) for mammals, from Gabrielson and Lincoln (1959) for birds, and from Wilimovsky (1954) for fish.

(Odobenus rosmarus) are most evident in the spring when they migrate past the island in their return from wintering areas. Other pinnipeds found near the island include harbor seals (Phoca vitulina), ribbon seals (Phoca fasciata), bearded seals (Erignathus barbatus), and the sea lion (Eumetopias jubata).

There are many birds on the island. Some of the most conspicuous are the lesser sandhill crane (Grus canadensis canadensis), lesser Canada goose (Branta canadensis leucopareia), emperor goose (Philacte canagica), willow ptarmigan (Lagopus lagopus), pomarine jaeger (Stercorarius pomarinus), long-tailed jaeger (Stercorarius longicaudus), arctic tern (Sterna paradisaea), and several passerines such as the snow bunting (Plectrophenax nivalis) and the Alaska longspur (Calcarius lapponicus alascensis). The sea cliffs on the western end of the island support large colonies of nesting sea birds, chiefly gulls (Larus spp.) and North Pacific murres (Uria aalge inornata) but also horned puffins (Fratercula corniculata), tufted puffins (Lunda cirrhata), pigeon guillemots (Cepphus columba), and parakeet auklets (Cyclorrhynchus psittacula). Among sea ducks, the most commonly seen include the Pacific common eider (Somateria molissima v-nigra), Steller's eider (Polysticta stelleri), harlequin duck (Histrionicus histrionicus), and the old squaw duck (Clangula hyemalis). Swarth (1934) has treated the birds of Nunivak Island in more detailed fashion.

Freshwater streams are spawning grounds for pink salmon (Oncorhyncus gorbuscha), dog salmon (O. keta), silver salmon (O. kisutch), and red salmon (O. nerka). Dolly varden trout (Salvelinus malma) are found in most of the major streams. Blackfish (Dallia pectoralis) occur in some of the ponds and lakes. Natives report grayling (Thymallus arcticus) present in one or two streams.

HISTORY.

Eskimo populations on the island were once larger and more widely distributed, although population figures are not available. At one time the natives lived in several villages around the perimeter of the island. The collapsed barabaras of old village sites can still be seen at most major bays and coves. During the late 1800's the native population suffered substantial reductions due to influenza and other introduced diseases. During the 1930's only two or three village sites were occupied year-round, the most important of these being Nash Harbor and Mekoryuk. Following the construction of a U.S. Bureau of Indian Affairs (BIA) school at Mekoryuk, the Nash Harbor residents moved to Mekoryuk. Today Mekoryuk is the only permanent village on the island. It has a population of about 300 Eskimos. Construction of an airfield, expansion of the BIA reindeer facilities, and establishment of the church at Mekoryuk helped to stabilize residency.

The reindeer industry was established on the island with the introduction of reindeer in the 1920's, and since that time has played an important part in the economy and life of the Eskimos on the island. Operation of the reindeer slaughtering facilities provides temporary employment for many of the natives during the fall harvest period. In addition, natives are allowed to take reindeer for personal use. The people still utilize the island's salmon resource in summer, and utilization of marine mammals continues, but the dependency upon these resources is not what it once was. Mekoryuk is today one of the more affluent villages in northwestern Alaska. Dog sleds have been replaced by gas-powered snow vehicles; new homes are under construction, and luxury items are common.

THE NUNIVAK ISLAND RANGE

Vegetation of arctic regions has received general treatment by several authors (Palmer and Rouse 1945; Porsild 1951; Weaver and Clements 1929). Characteristics of the vegetation of Nunivak Island agree with Weaver and Clements' (1929) general description of arctic tundra and positionally with Polunin's (1959) low arctic zone, although the Nunivak flora more closely approximates the species characterization he gives for the middle arctic zone. Nunivak Island is under the influence of maritime climatic regimes which impose a uniformity to the climatic environment and hence to the vegetation. This is of significance when considering causes of progressive or retrogressive short-term vegetation changes since such changes would not be expected to result from climatic influences. The extrusive geology of the island is responsible for some differences in vegetation from that of the mainland, which has a geology that is largely intrusive or depositional in character. The flat and featureless nature of much of the terrain affects drainage development and consequently vegetation development. Lava flows of Recent origin in the interior have not yet been vegetated. The basaltic rock indirectly affects vegetation through its effects on soil development and soil properties.

STUDY APPROACH.

Much of the work on vegetation in arctic Alaska has been descriptive in nature. The climax concept lends itself well to general description and vegetation type designation. Churchill and Hanson (1958) made a comprehensive review of the climax concept in arctic vegetation and concluded that the concept of climax is applicable to arctic situations characterized by non-directional changes and fluctuations about a mean. The climax concepts and their associated principles of dominance have found wider usage in arctic Alaska than the more sophisticated European systems of phytosociological studies. Perhaps European systems will receive greater attention with more detailed investigations.

Miller (Palmer 1938) and Palmer and Rouse (1945) are the only investigators who have reported studying the vegetation of Nunivak Island prior to the present study. These workers listed six vegetation types or subtypes on the island in their studies of succession on permanent quadrats. An extension of Palmer's classification was followed by the writer as a format in designating broad vegetation types on the island. Hanson (1953) has presented a synopsis of vegetation types in Alaska, discussing six major groups and 22 minor groups based on their physiognomy and major constituent species. Nunivak Island vegetation types correspond to several of Hanson's types. Comparison to this and other studies will be made in the discussion of range types.

<u>METHODS</u>.

In line with the objectives of this study, the procedure followed in studying the vegetation was to make a superficial description of general vegetation types segregated on the basis of dominance of one to several species. Line point transects 100 ft in length were employed on most transects. Point readings were made every 6 inches with one reading per point. Points were assigned to the first species hit or to non-vegetative bare ground, rock, or litter. Percentages of vegetative cover were determined by dividing the number of vegetative hits by the total number of points for each range type. Percentages of the vegetative cover according to species were determined by dividing the number of hits on a species within a range type by the total number of vegetative hits for each range type. Determination of range types was based on 47 transects comprising 9,141 point readings. Transects were subjectively placed in relatively homogeneous stands representing the various types. Study of vegetation types was limited largely to the perimeter of the island. Supplemental observations on interior areas were made from the air.

Plant species were identified by the writer. References used were Anderson (1959) and Hultén (1941-1950). Species identifications were crosschecked in the collections of the University of Alaska Herbarium. A list of all species collected on the island appears as Appendix A.

In addition to vegetation analysis, a very cursory inspection of the soils of different range types was attempted. Soil profile, depth to permafrost, and pH values were recorded. The pH determinations were made with a La Motte soil tester. Comments on soils are made in the descriptions of range types below. In general, soils on the island fit the descriptions found in Kellog and Nygard's (1951) review of soils in Alaska, and Tedrow and Cantlon's (1958) treatment of soil classification in arctic regions.

For purposes of discussion, illustration, and hopefully for eventual use in practical management planning, a range type map was prepared from aerial photographs, substantiated in part by ground observations (Fig. 2). Photographs used were nine-lens Coast and Geodetic Survey photos taken at a 1:20,000 scale. These photos were carried in the field for on-the-ground verification of types, where possible. The information was transferred to 1:63,360 scale U.S.G.S. topographic maps and subsequently to 1:250,000 scale U.S.G.S. maps by means of a Focal-matic Desk Projector.

RANGE MAP.

The types designated on the map (Fig. 2) are described below in terms of dominant cover species and physiognomic appearance, an approach necessary to photo interpretation of vegetation types (Stoeckeler 1948). Of the 10 range types and subtypes described below, the distribution of nine is shown on the map. The aquatic type is restricted to ponds and lakes, shown on the map as water bodies. The wet tundra peat mound subtype could not be differentiated on the photos.

Some problems were encountered in delineating types on the photos. The scale of 1:20,000 proved too small, and resolution was not clear enough for accurate identification of some types in some areas. Also, exposure differed enough on various photographs so that identification of types based on degree of shading had to be a relative judgment for each photo. Wet tundra was the most easily identified and hence the most accurately mapped type.

The dry tundra and grass hummock subtypes were much more difficult to separate because of their similarity in spectral affinities. Barren rock was identifiable in most cases.

The section of the island which presented the most difficulties and which is the least accurately mapped is the interior. Limitations of the photographs resulted in poor differentiation of types, partly because the development of vegetation in the interior is not as well advanced as in other portions of the island. Where crustose lichens were absent or dark in color, or where rock was dark in color and physiognomy not distinctive, rock fields had much the same appearance as vegetation. In much of the interior the grass hummock and dry tundra subtypes blend, and although differentiation can be made on the ground or at low altitude, these types and the intermediate expressions formed by environmental gradients lost their identity when viewed from high altitude. Type designation favored the grass hummock subtype because it was the more common.

RANGE TYPES.

The vegetation of Nunivak Island has been arranged into 10 range types or subtypes on the basis of dominant cover species and physiognomy. By using dominant cover species, identification of types from the ground, air, or from aerial photos was facilitated. The physiognomy of different types was used as a supplementary aid when cover characteristics were difficult to distinguish.

Wet Tundra.

Wet tundra is the most extensive type found on the island, covering about 57.5% of the area or about 637,905 acres (Fig. 2). It is present throughout the island, wherever low-lying or flat terrain impede drainage. It is most prevalent on the northern side of the island, with a broad band extending southward between the interior uplands and the western tip of the island, in the vicinity of Kikdooli Butte. There are also sizeable wet tundra areas on the eastern, southern, and western margins of the island and scattered patches in the interior.

The distribution of the wet tundra with respect to surface relief differs in various parts of the island in relation to the age of the landforms. In general, the aspect of the wet tundra west of Nash Harbor appears more mature than that of the remainder of the island. Drainage systems have steeper slopes and seem better established. Wet tundra in this area is usually found on the tops and upper slopes of flat-topped ridges. The aspect is relatively smooth. Peat mounds are rarely larger than a few feet in height in flat areas. Low ridges parallel to the slope as described by Johnson, et al. (1966) are present in the region. There are relatively few water bodies and few very wet, boggy areas. In contrast, wet tundra on the remainder of the island is often quite boggy with numerous water bodies. Peat mound development approaches small pingo dimensions. The drainage systems are not well developed. The ridges are rounded with the wet tundra occupying the lower slopes and valleys.

Peat Mound Subtype. Peat mounds rising as much as 12 ft above the surrounding tundra are common in waterlogged tundra areas. At one point on the coast near Cape Manning where the land is sinking in relation to sea level, a peat mound subtype has been sectioned by sea water so that the structure of several mounds is exposed. These mounds consist of 7-10 ft of peat overlying a silty-clay ice lens of undetermined thickness. The permafrost layer is 1-2 ft below the surface. A peat mound sampled near Nakooytoolekmiut, on the southeastern corner of the island, had permafrost at 8-10 inches. The pH ranged from 4.5 on the surface to 5.2 above the permafrost.

Peat mounds provide a drier microhabitat than the surrounding tundra. The vegetation on peat mounds differs substantially from the sedge-dominated wet tundra surrounding them and so was treated as a subtype of wet tundra. The species found on peat mounds are more characteristic of dry tundra except for the dominant cover species, _Rubus chamaemorus_, which forms 26% of the vegetative cover (Table 2). Lichens (mostly _Cladonia_ spp.), _Ledum decumbens_, moss, _Arctostaphylos alpina_, _Empetrum nigrum_, and _Vaccinium vitis-idaea_ make up an additional 69% of the vegetative cover. The remaining vegetation is composed of _Spirea beauverdiana_, _Betula nana exilis_, _Carex bigelowii_, _Calamagrostis canadensis_, and _Trientalis europea_. Vegetation covers 77% of the ground area.

Tidal Wetland Subtype. The tidal wetland subtype covers about 0.4% of the island or about 4,438 acres. It occurs in areas subject to flooding by sea water, especially during fall storms. Some small tidal wetland areas are present in the small bays on the north side of the island, but this subtype is best developed behind the sand dunes of the south side where low relief and tidal flats are found, as in Duchikthluk Bay. Species are adapted to saline conditions and differ from the typical wet tundra species. As site conditions approach the wet tundra environment, elements of both mix so that intergradation of types occurs. This gradient is usually steep, however, and the differences could be detected on the aerial photos.

This subtype was not studied to any extent but is described by Hanson (1951). His description of a saline community included Carex subspathacea, C. glareosa, Potentilla pacifica, Stellaria humifusa, Poa eminens, Pucinellia borealis, and Elymus mollis as important species. One transect run on Nunivak Island showed Carex spp. as the dominant vegetation (63%). Other species included Elymus mollis, Stellaria humifusa, Poa eminens, Salix ovalifolia, and Potentilla pacifica. Vegetation covered 86% of the ground.

Wet Tundra Subtype. The typical wet tundra is one of the most uniform types on the island in both appearance and species composition. This subtype corresponds to Palmer and Rouse's (1945) wet-tundra sedge-lichen type. This subtype forms most of the wet tundra type on the island, covering more than 50% of the total land area.

Carex aquatilis and Eriophorum angustifolium are the dominant cover species, comprising about 58% of the vegetative cover. The number of important cover species is relatively small. Salix spp. (including S. ovalifolia), Sphagnum spp., moss, Empetrum nigrum, and Eriophorum scheuchzeri make up an additional 29% of the cover. Other species found were Calamagrostis canadensis, Potentilla palustris, Rubus chamaemorus, Ledum decumbens, Petasites frigidus, Vaccinium vitis-idaea, lichens, Polemonium acutiflorum, Rumex arcticus, and others (Table 2).

For most wet tundra species presence is determined by wetness. Very wet areas have a high proportion of Sphagnum spp. in addition to the dominant _Carex aquatilis_. _Potentilla palustris_ is also found in wet situations. Some small wet tundra areas are grown almost exclusively to _Eriophorum angustifolium_. _Eriophorum scheuchzeri_ has invaded in disturbed areas. This is very evident in the Mekoryuk area where concentrations of reindeer are held in corrals each year. In areas of severe disturbance where vegetation has been destroyed by trampling, moss (mostly _Hylocomium_ spp.), _Deschampsia caespitosa_, _Pucinellia phryganodes_, and _Ranunculus pygmaeus_ are primary invaders which precede revegetation by _Carex aquatilis_ and _Eriophorum angustifolium_. If the soil is not heavily saturated, _Deschampsia caespitosa_, _Festuca rubra_, _Poa_ spp., and _Trisetum sibiricum_ form a sod which is later replaced by sedge growth.

Browse species such as _Betula nana exilis_, _Empetrum nigrum_, and _Ledum decumbens_ are present on drier sites. Species such as _Chrysanthemum arcticum_, _Petasites frigidus_, and _Polemonium acutiflorum_ have wide tolerances and are found in most regions. Prostrate _Salix_ spp. vary in abundance in different areas but not in correlation to moisture. _Calamagrostis canadensis_ is found in places where slope or soil movement increases drainage and brings mineral soil within reach of the grass.

All wet tundra soil sites examined were similar. The substratum is peat, generally 12-18 inches in depth, with a pH of 5.2-5.4, underlain by a brownish-gray clay soil or a gley. The permafrost level varies with the time of observation, but by midsummer the ground is usually thawed to about 16 inches.

Dry Tundra.

The dry tundra is the third most abundant range type on the island. It is most common in the interior portions of the island and on the western tip, covering about 13.6% of the island or about 150,878 acres.

Dry Tundra Subtype. The dry tundra subtype is found on sloping terrain with good drainage, often where the soil depth is quite shallow and where cryopedologic processes are at a minimum. Several soil sites were examined near Nash Harbor and Dahloongamiut Lagoon. Commonly a surface layer of dark brown, organic soil with a pH of 5.2-5.4, usually 2-6 inches in depth overlies a light brown, clay soil 2-6 inches in thickness with a pH of 5.4-5.6, often mixed with rocks, especially in areas experiencing congeliturbation. In places the soil is only a few inches deep. In others the two layers described above are underlain by a gley. Permafrost, when present, is found at depths of 5-8 inches in June and 12-14 inches in July.

The dry tundra subtype is dominated by *Empetrum nigrum* which forms 29% of the vegetative cover. *Carex bigelowii*, lichens (mostly *Cladonia* spp.), moss (mostly *Hylocomium* spp.) and *Arctostaphylos alpina* are also important cover species contributing 42% of the cover. In addition, *Ledum decumbens*, *Luzula nivalis*, *Vaccinium uliginosum*, *Elymus mollis*, *Poa* spp., *Trisetum sibiricum*, *Betula nana exilis*, *Sedum roseum*, and *Vaccinium vitis-idaea* are common components. Vegetative cover totalled 84% of the ground area.

The dry tundra, with less uniformity than the wet tundra and with a greater number of species, presents a varied character on different parts of the island. Although characteristically dominated by

Empetrum nigrum and Carex bigelowii, dry tundra vegetation can vary in the abundance of these and other species such as Luzula nivalis, Ledum decumbens, Arctostaphylos alpina, and especially lichens. Some areas visited on Cape Mendenhall, in the Cape Corwin region, and Twin Mountain have relatively good lichen growths, up to 6 or 8 inches in depth in some locations. Lichens in such areas form a large proportion of the cover. Empetrum nigrum is of minor extent while Carex spp. are subdominant to the lichens, a condition which approaches Palmer's (1945) description of the dry tundra climax. Such dry tundra conditions have high vegetative cover. On the other hand, much of the dry tundra of the island and all of the dry tundra west of Nash Harbor have sparse lichen growth. The reason for this lack of lichens is discussed in another section. It is interesting to note that presence of Spirea beauverdiana, Vaccinium uliginosum, and to a lesser extent Betula nana exilis is similar to that of lichens, these species being most abundant on the southeast quarter of the island, and completely absent from the western third of the island, at least in those areas visited.

Portions of the island such as the dry tundra just north of Duchikthluk Bay, and even more graphically, the dry tundra of the western tip of the island exhibit poor vegetation growth with discontinuous cover and considerable mineral soil exposed. In places the vegetation is in a severely retrogressed state with growth limited to small clumps of Empetrum nigrum growth. Parts of these regions have experienced substantial frost action and congeliturbation. Large expanses have Arctagrostis latifolia and Calamagrostis canadensis present, probably as a result of the availability of mineral soil.

Also present only on the western tip of the island are regions of solifluction lobe development similar to that which is common in other areas of Alaska. Solifluction lobes are most prevalent just west of Nash Harbor. Descriptions found in Everett (1966) and Johnson, et al. (1966) apply to those of Nunivak Island.

The dry tundra subtype corresponds to elements of Hanson's (1953) dwarf birch-heath-lichens type and his blueberry-heath-lichens type, and to Palmer and Rouse's (1945) tundra-lichen and heath types.

Alpine Tundra Subtype. The alpine tundra subtype occurs on numerous hills and mountains, at higher elevations than the dry tundra. Alpine tundra covers 0.4% of the island or about 4,438 acres. It is similar to the dry tundra in many respects, and both types blend together. *Empetrum nigrum* and *Arctostaphylos alpina* are the dominant species together forming 29% of the vegetative cover. *Dryas octopetala*, *Salix arctica*, moss, *Ledum decumbens*, and *Oxytropis nigrescens* are close behind in their individual contributions to cover (their total is 43%). Lichens, *Hierochloe alpina*, *Vaccinium vitis-idaea*, *Betula nana exilis*, *Carex bigelowii*, *Loiseleuria procumbens*, and *Luzula nivalis* are also common species. Vegetation covers 84% of the ground.

Empetrum nigrum, *Arctostaphylos alpina*, and *Betula nana exilis* predominate along lower elevations of the subtype where the alpine tundra adjoins the dry tundra, while *Dryas octopetala*, *Salix arctica*, and *Oxytropis nigrescens* are found on the uppermost portions of the type.

Alpine tundra soils were inspected on Ingriruk Hill and on Twin

Mountain. The soil on top of Ingriruk Hill consists of a 5 inch layer of rocky, dark reddish-brown soil with a pH of 5.6 overlying a red alkali basalt parent material with a pH of 5.8. On Twin Mountain a 5-6 inch layer of dark brown, organic soil with a pH of 5.2-5.4 covers 6-14 inches of unconsolidated red cinder with a pH of 6.4.

The alpine tundra subtype is similar to Hanson's (1953) alpine bearberry-mountain cranberry type, his alpine dryas type, and his alpine sedge-alpine dryas type. Palmer's (1945) alpine heath is also similar.

Grass-browse.

The grass-browse type is the second most abundant range type on the island, covering 259,599 acres or about 23.4% of the island. With the dry tundra it covers most of the interior uplands and drier portions of the island (Fig. 2). The grass-browse type has been divided into the grass hummock and riparian grass-browse subtypes.

Grass Hummock Subtype. As a distinct vegetation subtype, the grass hummock subtype is often difficult to separate from the dry tundra subtype as the latter will often have a hummocky appearance, and species composition of the two subtypes can grade imperceptibly into each other. Environmental gradients are broad. The grass hummock subtype is generally found along the edges of, and intermingled with, the wet tundra type, in drainage channels adjacent to dry tundra or in broad areas which experience water movement and frost action in the spring. Hanson (1950) goes into mound and hummock formation, but it is Hopkins and Sigafoos (1951) who have made detailed studies of the process. According to these authors, grass and sedge tussock forms occur in areas where the mineral soil and water table are close to the surface. Congeliturbation can lead to tussock formation. In the case of Calamagrostis and Carex tussocks, the culms contribute to tussock formation.

As a well defined and widespread vegetative subtype the grass hummock subtype occurs most extensively in the southeastern portion of the island near Twin Mountain and Cape Corwin, in large areas of the interior, and in tracts bordering the northern wet tundra areas.

The grass hummock subtype vegetative cover is high as with other types, with 90% of the ground being covered. Typically dominated by Festuca altaica (16%) or Calamagrostis canadensis (13%), or both, other plants including Empetrum nigrum, mosses, Artemisia laciniata, and Salix pulchra are also important contributors, adding 36% of the vegetative cover. Other characteristic species include lichens, Arctagrostis latifolia, Carex bigelowii, Angelica lucida, Sanguisorba sitchensis, Petasites frigidus, Artemisia arctica, Sedum roseum, and others (Table 2).

Palmer and Rouse (1945) give a general description of the grass-browse type on Nunivak Island, but where they described an Arctagrostis-willow aspect, this study indicates Calamagrostis is now of more importance as a cover species. On the whole, the grass hummock subtype agrees most closely with Hanson's (1953) species description of the greenleaf willow type, but it could be classified under his grassland types, particularly the Festuca altaica phase.

The grass hummock subtype is a broad category which has a wide range in aspect and species composition. The most robust expression of the subtype is in the southeast portion of the island and in the region near Muskox Mountain and Kimijooksuk Butte. It is in these areas that Festuca altaica is most important as a cover species and variety of species is greatest. In the Twin Mountain area Salix pulchra is abundant, and the fern Dryopteris oreopteris is common.

On the western end of the island the subtype is restricted to some drainage channels where conditions for hummock formation are favorable. It is also present as a fringe between wet and dry tundra where soil movement and disruption of the surface organic layer occurs. Such fringe areas are usually narrow and small in area, although in toto they comprise a substantial area. Soil slumping along the bluffs on the west end creates many Calamagrostis-Arctagrostis fringe areas. There are fewer species in the subtype on the west end. Dominance is by Calamagrostis canadensis, Carex spp., and Arctagrostis latifolia. Festuca altaica is present and in a few areas is dominant, though not in typical grass hummock subtype. One such area on the bluff immediately west of Nash Harbor has the aspect of a temperate bunchgrass range. Only a few acres in size, it is the only such stand seen on the island. This stand grows over an alkali eruption center where the soil is a dark reddish-brown with a pH of 6.7. Nearby on the same soil type but at a pH of 5.2 and permafrost at 6 inches, the vegetation is dominated by Arctagrostis latifolia.

Of interest is the fact that Eriophorum vaginatum tussocks are almost entirely absent from the island, whereas this type is quite common in northwestern Alaska. A few tussocks of this species are found on

Cape Mendenhall. Most are old and decadent.

Soils sampled in the grass hummock subtype are usually acidic. The pH values range from 5.0 to 5.8 in upper soil layers which vary in color from dark brown organic to a reddish-brown cinder soil. In well developed hummocks permafrost is found within 8-14 inches from the surface in a yellowish-brown silty-clay core.

Riparian Grass-browse Subtype. The riparian grass-browse subtype is similar in species composition to the grass hummock subtype, but its occurrence is restricted to the borders of streams and rivers, with best development where the stream channels are braided. The subtype is characterized by a great variety of species with local variations in composition existing, depending on water availability, soil depth, stream permanency, etc. The species are adapted to conditions of flooding. *Calamagrostis canadensis* dominates the cover (16%) with *Salix* spp. (10%), *Salix reticulata* (6%), moss (6%), *Festuca altaica* (5%), *Sanguisorba sitchensis* (5%), and *Salix pulchra* (4%) heading a long list of species (Table 2). Vegetation covers 92% of the area.

The greatest differences in the subtype between different regions is in the presence of shrub willows. The two species involved, *Salix alaxensis* and *S. pulchra*, occur primarily along streams but are not confined to such locations and are absent from many streams. *S. pulchra* is the most abundant willow, growing along streams east of a line between Nash Harbor and the Jayalik River. There are no shrub willows on the western tip of the island. The cause of this lack of willows is unknown. Streams in this area appear similar in character to eastern streams supporting willows. Dense growths of *S. pulchra* are best developed from Cape Corwin north and west to the Mekoryuk region. Thick stands were noted in wet tundra areas where there is water seepage or flow. This species is also present in the grass hummock subtype growing between the hummocks.

Salix alaxensis distribution is much more restricted to the riparian zone. Growth of this species on dry tundra or grass hummock subtypes was seen only in the Iookswarat Bay - Ingrijoak Hills region west of Mekoryuk. This can probably be attributed to the different soil parent materials derived from the sedimentary deposits in that area. Generally speaking, *S. alaxensis* is not very abundant, and its distribution along streams is spotty and discontinuous. Some streams on the east coast have thick stands, but the most extensive growths occur along the south side of the island from Cape Corwin to the west fork of the Binajoaksmiut River. On the north side the willows grow as far west as Dadinowiky Creek. These willows are the tallest vegetation on the island. Many stands are old and well established, often with a thick and almost pure *Calamagrostis* understory.

The riparian grass-browse subtype corresponds to Hanson's (1953) feltleaf willow and greenleaf willow types.

Only one soil sample was studied in the subtype on the Ingrimiut River. A shallow, brown loam soil a few inches in depth, overlying gravel, was found to have a pH of 6.2. *Calamagrostis canadensis* grew on the site. Where a vegetative sod had developed farther from the stream, the pH lowered to 5.4.

Beach Grass-forb.

The beach grass-forb type is limited to coastal sand dunes and strand areas of the island. Prevailing wind and ocean currents have favored dune development on the southern and southwestern coasts of the island, whereas the northern and eastern coasts are largely lacking in such development. The beach grass-forb type covers about 0.4% of the island or about 4,438 acres.

Elymus mollis is the dominant species (60% of cover), with *Lathyrus Maritimus*, *Festuca rubra*, *Calamagrostis lapponica*, *Achillea borealis*, *Artemisia arctica*, *Cnidium ajanense*, *Poa* spp., and *Conioselinum benthami* the most common associated species. *Arenaria peploides* is one of the earliest invaders on sand but contributes little to the vegetative cover. Vegetation of the beach grass-forb type covers 81% of the area.

Typically the vegetation is dominated by *Elymus mollis* near the sea, with progressive invasion of higher seral stages as one moves inland. The dominant *Elymus*-*Lathyrus* association gives way to a complex of other genera including *Arctostaphylos*, *Artemisia*, *Carex*, *Deschampsia*, *Empetrum*, *Festuca*, *Trisetum*, and others, with cover dominants varying as the exposure, sand movement, and moisture conditions change. Generally there is a transition zone where components of both the beach grass-forb and the adjoining wet tundra or dry tundra are mixed. Such transition zones are usually broader with the dry tundra than with the wet tundra.

The vegetation which represents the early succession stages on the sand dunes was quite uniform at all areas visited. Early establishment by *Arenaria peploides*, *Elymus mollis*, *Lathyrus maritimus*, and *Senecio* pseudo-arnica bind the shifting sands and make conditions favorable for the formation of a more complex community. The Elymus belt varies in width. The widest seen was about 100 yards in width.

With the addition of organic material to the relatively neutral sandy soil, numerous species are established whose growth in places approaches the appearance of meadows. Grasses including Deschampsia caespitosa, Festuca rubra, Poa arctica, and Trisetum sibiricum may form a sod. Achillea borealis, Artemisia arctica, Cnidium ajanense, Potentilla villosa, Viola langsdorfii, and others enrich the flora. Deposition of debris from storm drift adds to the organic content of the soil. Angelica lucida and Conioselinum benthami grow particularly well in such areas.

Not all areas visited exhibited good vegetation growth. Some dunes had poor growth behind the Elymus stands. Cover was very sparse with crustose lichens, occasional Elymus, Arctostaphylos, and Empetrum plants, and a dried moss crust making up most of the cover. Drainage, deposition of blowing sand, and disruption of the original cover by grazing are possible causes for such conditions.

Once a vegetative cover is established on the sand, the dune character can be long-lasting. At Dooksook Lagoon, on the west end of the island, a modified beach grass-forb vegetation exists on old dunes which overlie basalt bluffs and are now as much as 100 ft above sea level.

On the south side of the island the sand dunes are moving seaward under the influence of prevailing northwest winds. As the dunes migrate, hollows formed by wind fill with water and are colonized by *Juncus balticus*. As stabilization occurs *Carex* spp. replace the *Juncus*. Higher dune remnants are vegetated by *Empetrum nigrum*, *Arctostaphylos alpina*, *Betula nana exilis*, and lichens. Among lichens *Stereocaulon* spp. are most commonly the first established.

The soils of the beach grass-forb type are more nearly neutral than any other soils on the island. Soils were examined at most major dune areas on the island and were consistently the same. Permafrost was not encountered. The pH values range from 6.6 to 6.8 in sand with little organic matter. As vegetative cover and hence organic material increase, the sand turns progressively browner and more acid. The pH values are generally in the 6.0-6.4 range but reach 5.4 and lower when a peat covering is present.

Hanson (1953) includes the beach grass-forb type in his grassland types. Palmer and Rouse (1945) designated a sand dune type for the typical *Elymus-Lathyrus* association described above and added a beach transition type for progressive community types. Their description was based on a transition type near Mekoryuk, and so does not apply to numerous other beach transition associations on the island.

Barren Rock.

Although not truly a vegetation type, the barren rock type is included as a range cover type. Barren rock covers about 2.5% of the island or about 27,735 acres. There are extensive areas of barren rock in the interior of the island on Roberts Mountain, on Kikdooli Butte, on Seemalik Butte, in regions of recent lava flows near Karon Lake and

Nanwaksjiak Crater, and in smaller patches along bluffs, buttes and stream channels. Vegetative cover ranges from a sparse crustose lichen cover on lava beds to a lithosol dry tundra vegetation.

Aquatic.

Nunivak Island has a large number of small shallow ponds and lakes which support various amounts of aquatic vegetation. An estimate of the area covered by this type is about 2.0% or about 22,188 acres, but it may possibly be much higher. Species most commonly found are *Hippuris vulgaris*, *Ranunculus palasii*, and *Carex aquatilis*. The number of species is low.

Table 2. Cover percentages of species in vegetation types of Nunivak Island, Alaska.

	WET TUNDRA			DRY TUNDRA		GRASS-BROWSE		BEACH GRASS FORB
Species	Peat Mound	Tidal Wetland	Wet Tundra	Alpine Tundra	Dry Tundra	Grass Hummock	Riparian Grass-browse	Beach Grass-forb
Lichens	20		T*	5	12	4	T	
Lungwort							T	
Mosses	12		4	9	11	9	6	
Sphagnum spp.			8			T	T	
Lycopodium selago					T			
Equisetum arvense						T	3	
Equisetum spp.					T			T
Dryopteris oreopteris						T		
Betula nana exilis	2		T	3	2			
Campanula lasiocarpa				T	T			T
Arenaria peploides								T
Stellaria humifusa		5						T
Stellaria spp.					T		T	T
Achillea borealis							1	4
Arnica lessingii						T	T	
Artemisia arctica				T		2	1	3
A. laciniata				T	T	9	3	
Chrysanthemum arcticum		2	T				T	
Petasites frigidus			1			2	T	T
Senecio resedifolius					T			

Table 2. (Continued)

Species	WET TUNDRA		
	Peat Mound	Tidal Wetland	Wet Tundra
Taraxacum			
Cornus suecida			
Sedum roseum			T
Cardamine pratensis			
Carex aquatilis			38
C. atrata			
C. bigelowii	T		
C. stylosa			
Carex spp.		63	
Eriophorum angustifolium			20
E. scheuchzeri			4
Empetrum nigrum	7		4
Arctostaphylos alpina	8		T
Ledum decumbens	16		1
Loiseleuria procumbens			
Vaccinium uliginosum			
V. vitis-idaea	6		T
Corydalis pauciflora			
Geranium erianthum			
Alopecurus alpinus			

DRY TUNDRA		GRASS-BROWSE		BEACH GRASS FORB
Alpine Tundra	Dry Tundra	Grass Hummock	Riparian Grass-browse	Beach Grass-forb
		T	T	
			T	
	1	2	4	
		T	T	
			T	
		T	1	
3	12	4	2	
			T	
			2	
15	29	11	1	
14	7			
8	3	T		
2				
1	3			
3	1	T	T	
		T	T	
			2	
		T	2	1

Table 2. (Continued)

	WET TUNDRA		
Species	Peat Mound	Tidal Wetland	Wet Tundra
Arctagrostis latifolia			
Calamagrostis canadensis	T		2
Elymus mollis		9	
Festuca altaica			
F. brachyphylla			
F. rubra		17	T
Hierochloe alpina			
H. odorata			
Poa arctica			
P. eminens		2	
Poa spp.			T
Pucinellia spp.		T	
Trisetum sibiricum			
Luzula campestris			T
L. nivalis			
Lathyrus maritimus			
Oxytropis nigrescens			
Lloydia serotina			

	DRY TUNDRA		GRASS-BROWSE		BEACH GRASS FORB
	Alpine Tundra	Dry Tundra	Grass Hummock	Riparian Grass-browse	Beach Grass-forb
			4	T	
		T	13	16	5
		2			60
		T	16	5	
		T			
				3	6
	4				
		T		T	
		2			1
		T	T	T	T
		T			
	T	2		T	
			T	T	
	2	3			
		T			12
	6	T			
	T	T			

Table 2. (Continued)

Species	WET TUNDRA Peat Mound	Tidal Wetland
Tofieldia coccinea		
Epilobium angustifolium		
E. latifolium		
Polemonium acutiflorum		
Polygonum viviparum		
Rumex arcticus		
Androsace chamaejasme		
Primula tschuktschorum		
Trientalis europea		
Pyrola minor		
Aconitum delphinifolium		
Anemone narcissiflora		
Caltha palustris arctica		
Ranunculus pygmaeus		
Dryas octopetala		
Potentilla pacifica		T
P. palustris		
Rubus arcticus		

	DRY TUNDRA		GRASS-BROWSE		BEACH GRASS FORB
Wet Tundra	Alpine Tundra	Dry Tundra	Grass Hummock	Riparian Grass-browse	Beach Grass-forb
	T				
			T	T	T
				T	
T					
	T	T	T	1	
T				T	
		T			
		T		T	
			T	T	
T					
		T		T	
	1			T	
				T	
T					
	10				
2				T	
			1	1	

Table 2. (Continued)

Species	WET TUNDRA		
	Peat Mound	Tidal Wetland	Wet Tundra
R. chamaemorus	26		2
R. stellatus			
Sanguisorba sitchensis			
Spirea beauverdiana			T
Salix alaxensis			
S. arctica			
S. ovalifolia		2	
S. pulchra			
S. reticulata			
Salix spp.			9
Saxifraga punctata			
Lagotis glauca			
Pedicularis langsdorfii			T
P. oederi			
P. verticillata			
Angelica lucida			
Cnidium ajanense			
Conioselinum benthami			

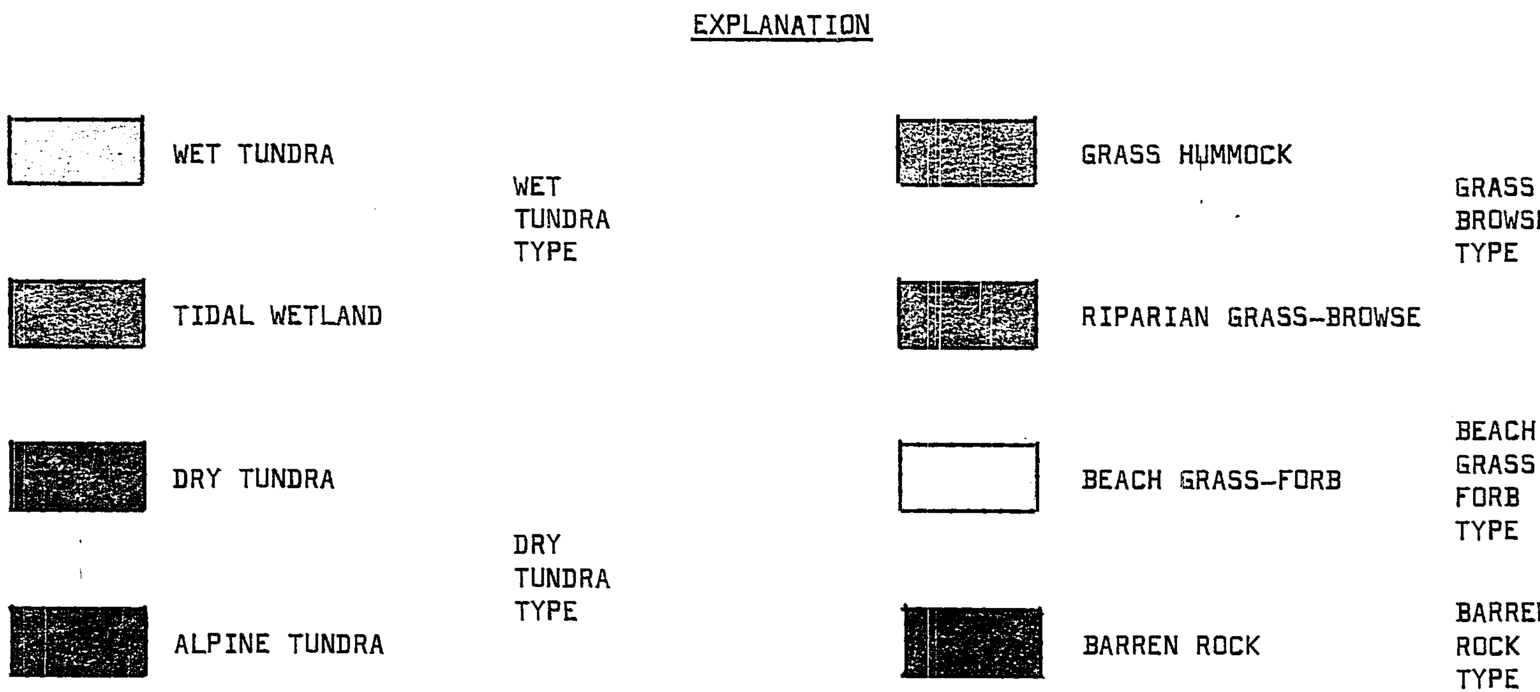
DRY TUNDRA		GRASS-BROWSE		BEACH GRASS FORB
Alpine Tundra	Dry Tundra	Grass Hummock	Riparian Grass-browse	Beach Grass-forb
		T	T	
		1	T	
		3	5	
		T	T	
			T	
9	T			
	T	T		
		8	4	
	T	T	T	
			10	
		1		
			T	
T	T	T		
			T	
T				
		3	2	1
	T		T	2
				1

Table 2. (Continued)

Species	WET TUNDRA			DRY TUNDRA		GRASS-BROWSE		BEACH GRASS FORB
	Peat Mound	Tidal Wetland	Wet Tundra	Alpine Tundra	Dry Tundra	Grass Hummock	Riparian Grass-browse	Beach Grass-forb
Ligusticum hulteni				T			T	
L. multellinoides				T				
Valeriana capitata					T			
Viola langsdorfii						1	3	T
VEGETATIVE COVER	77	86	93	84	84	90	92	81
BARE GROUND, ROCK, LITTER	23	14	7	16	16	10	8	19

* Trace, less than one percent.

Figure 2. Range types of Nunivak Island, Alaska.



Map from U.S. Geological Survey, Alaska Topographic Series, 1952 and 1954, Cape Mendenhall and Nunivak Island quadrangles, scale - 1:250,000.

MUSKOX

The study was not concerned with detailed biological characteristics of muskox. This subject has been treated by several authors (Palmer and Rouse 1935, Pedersen 1958, Tener 1954 1954b 1965). Further information is available through the U.S. Fish and Wildlife Service, Bethel, Alaska.

TAXONOMY.

The muskox (*Ovibos moschatus*) is a member of the family Bovidae. It has characteristics of both the genera *Ovis* and *Bos*. Its fecal droppings, hairy muzzle and shorter left sac of the reticulum are similar to *Ovis*, while the absence of the midfissure of the lip, presence of numerous cotyledons in the placenta, and presence of four mammary glands are similar to *Bos* (Tener 1954b). The bison was previously considered the muskox's closest living relative, but serological testing by Moody (1958) indicated closer affinities to sheep and goats than to cattle and bison. Simpson (1945) considered the takin (*Budorcas*) as the closest living relative of the muskox.

Allen (1913) recognized three subspecies of *Ovibos moschatus*. These were the barren ground muskox (*O. m. moschatus* Zimmerman), the subspecies extirpated from Alaska; the Hudson Bay muskox (*O. m. niphoecus* Elliot); and the white-faced muskox (*O. m. wardi* Lydekker), the subspecies native to Greenland and transplanted to Nunivak Island.

FOSSIL RECORD AND DISTRIBUTION.

The muskox was once found in Pleistocene tundra environments in northern Europe and Asia as well as North America (Tener 1954b). Its occurrence in southern parts of North America was followed by a northward movement with the retreating ice. Fossil muskox remains (several genera) have been found in Mississippi, Iowa, Oklahoma, Missouri (Hay 1930), Indiana (Tener 1954b), Texas (Peterson 1946), and other states (Gilmore 1941, Hay 1915), but southern Ovibos specimens have been relatively rare. Ovibos specimens of late Pleistocene age have been found near areas of previous glaciation in Pennsylvania, New Jersey, New York, and southern Ontario (Kitts 1953). Ovibos became extinct in Europe and Asia in prehistoric times. Depredations on muskox populations by man in North America in historic times reduced the muskox's once wide (though sparse) distribution to parts of northern Canada and Greenland.

RECENT HISTORY IN ALASKA AND CANADA.

The introduction of firearms and the demands of fur traders, wintering whaling parties, and explorers initiated a decline in North American populations which reached an alarming stage by the late 1800's. Reports conflict as to the date of the last recorded Alaskan muskox. The generally accepted date is 1865 when a herd was killed near Barrow (Manville and Young 1965). A report received by Irwin McK. Reed at Nome from a music teacher in 1905 stated that two Frenchmen killed a herd of 15 or 20 at Chandler Lake in 1898 (Warwick, J. W. 1940. Field notes. L. J. Palmer Collection, University of Alaska).

Muskox populations in Canada were also seriously reduced by the early 1900's, but protective Canadian legislation in 1917 and subsequent measures such as the establishment of the Thelon Game Sanctuary in 1927 resulted in partial population recoveries to a level of about 10,000 (Tener 1965). Tener has reviewed the history and present status of the muskox in Canada (Tener 1958).

Greenland muskox also suffered some reductions. The Danish government enacted protection measures beginning in 1950. Transplantations involving Greenland muskox were made to Sweden, Iceland, Norway, Spitsbergen, and Nunivak Island, Alaska (Lønø 1960). The transplants to Sweden and Iceland were unsuccessful.

The Nunivak Herd.

The U.S. Bureau of Biological Survey imported 34 muskox from Greenland in 1930 following congressional appropriation of funds for that purpose. The herd was composed of 17 calves, 16 yearlings, and one two-year-old animal, of which 15 were males and 19 were females (Palmer and Rouse 1935). The animals were taken to the Biological Survey Experiment Station at College, Alaska, where they remained until 1935 and 1936. During this time studies of domestication and feeding trials were conducted. When the objectives of the program were changed, two pairs of muskox were introduced to Nunivak Island, with the intent of transplanting the remainder to the Barrow region in hopes of re-establishing north slope muskox populations (Palmer 1935). In 1936 this plan was abandoned and the remaining 27 muskox were moved to Nunivak Island and released.

POPULATION GROWTH.

Summer aerial censuses of muskox have been conducted annually on

Nunivak Island by the U.S. Fish and Wildlife Service (USFWS) since 1947. The coverage of the island has been in straight line patterns with prominent landmarks used as guides. The length of time required for the surveys has varied from two to three days to over a week, depending on the weather. Although extended survey periods may have resulted in duplication of counts (due to the movement and recombination of herds), the population totals in terms of calves and total numbers of muskox yielded by the surveys have probably been quite accurate. Table 3 represents the data obtained from the surveys. All counts have been complete except for the 1966 survey when a small portion of the island was not censused. It can be expected that future counts will also be incomplete or subject to greater inaccuracies as the population increases. Some surveys have been conducted in late winter, and these serve to supplement the summer data.

From the time of introduction in 1935 and 1936 until the annual aerial surveys began in 1947, the numbers of muskox on the island went largely unrecorded. The initial transplants in 1935 and 1936 involved 14 females and 17 males (Palmer 1938). Of the females, 11 were adults, one was 2 years old, and two were yearlings. Of the males, five were adults, four were 2 years old, and eight were yearlings. There were no calves produced in 1936, before the transplant. No counts were made in 1937, but calves were produced that year because Palmer (1938) counted two yearlings and credited an Eskimo report with an additional eight yearlings, or a possible total of 10 in 1938. In 1938 Palmer (1938) reported 50 muskox on the island of which nine, and possibly 11, were calves. Subsequent reports of numbers were largely inaccurate until 1948 when Rouse (1948) reported 56 animals, seven of which were calves. Rouse also reported probable losses of 6-10 animals from the original stock.

Apparently considerable losses were sustained by the population between 1938 and 1948, since practically no gains in numbers were made during this period. Failure to breed is an unlikely cause since good reproductive success was recorded by Palmer soon after the introduction. The cause for the lack of population growth is unknown. During this same period reindeer populations reached their highest levels and then declined sharply (Table 7). High reindeer populations may have had some influence on the muskox population during this period.

Muskox population increases during the period 1936 to 1938 were 23.8% per year. From 1948 to 1965, the herd increased at a rate of 12.9% per year. Assuming this rate remains constant until 1975 and no removals by transplants or hunting take place, there would be 937 muskox by 1970 and 1,718 muskox by 1975. Such an assumption is based on the premise that there would be no limitations on population growth.

It is possible that growth rates will be reduced before the population reaches 1,718 if winter ranges become limiting in such a manner as to reduce reproductive success.

Table 3. Muskox population counts 1936 - 1966*

Year	Adults, Subadults and Yearlings	Calves	Total Count	Recorded Loss
1936			31	1
1937		10?		
1938	41	9-11	50	
1945				2
1947			47-49	
1948	50	7	57	5
1949	57	8	65	1
1950	54	7	61	4
1951	60	16	76	2
1952	68	9	77	2
1953	75	15	90	3
1954	79	21	100	4
1955	97	19	116	4
1956	100	26	126	9
1957	118	25	143	2
1958	149	32	181	1
1959	167	39	206	6
1960	199	57	256	2
1961	224	69	293	3
1962	275	78	353	6
1963	333	73	406	9
1964	365	102	467	28**
1965	402	110	512	26**
1966	460	109	569***	16

* 1936, 1937, 1938 figures from Palmer (1938); all other data from files of USFWS, Clarence Rhode National Wildlife Range, Bethel, Alaska.

** Includes removal of 23 calves in 1964 and 10 calves in 1965 by John Teal, Project Supervisor, Muskox Project, University of Alaska.

*** Incomplete count.

MORTALITY.

There is a fairly good record of muskox mortality on Nunivak Island. A large percentage of the mortality which has occurred on the island has been recorded, and some reports of muskox that have washed ashore on the mainland have also been received. Natives report dead animals, and the annual aerial muskox surveys in summer account for many records.

Mortality of muskox has been relatively low since 1936 (Table 4). Since introduction in 1935 and 1936, approximately 840 calves have been produced by the Nunivak herd. If the original transplant of 31 is added to this figure, a maximum of about 870 muskox would be present, barring any mortality. The July, 1966, population estimate was 620 muskox. In addition to the 33 muskox removed by John Teal in 1964 and 1965, about 220 animals have died since 1936. Of these, 103 have been recorded (Table 4). Of the recorded losses, known causes of mortality accounted for 36. These mortality factors are discussed below. The remaining 67 were attributed to unknown natural loss, including death due to old age, sickness and malnutrition.

There are no wolves or other potential predators on the island; these are important mortality factors on Canadian muskox (Tener 1965). Occasional loose dogs from the village prey on reindeer, but no evidence of dog predation on muskox has been found. Foxes do not affect muskox.

Whereas accidental deaths are rare in Canada (Tener 1965), accidents are the major cause of identified losses on Nunivak Island. Of these, loss to winter ice is probably of greatest importance. Muskox are known to wander out on the sea ice in winter. Nelson Island, which is almost contiguous with the mainland, is visible from the northeast corner of the island and may act as an inducement to movements across Etolin Strait, which is rarely, if ever, frozen over. Losses to winter ice can be significant if whole groups break through the ice. It is likely that much of this loss is never recorded as only a few of the carcasses wash up on the mainland or on the island. Of the 36 mortalities with known cause of death, six were ascribed to losses on ice.

Falls from cliffs on the western end of the island are suspected of being an important cause of loss even though only three muskox are known to have died in this manner. The bluff areas are heavily used in winter, and some loss is suspected of having occurred when snow cornices collapse. Here again discovery of carcasses is low as the muskox fall directly into the sea or onto sea ice which drifts away in the spring.

Five muskox are known to have drowned while swimming across bays or after falling through thin river ice. The importance of such losses is unknown.

Four muskox died in bogs after they became mired and were not able to extricate themselves. Palmer (1938) believed bogs to be the greatest potential factor of loss to muskox on the island, but apparently it has been of minor importance.

One cow was observed gored. This form of mortality is thought to be rare, even considering fighting between rutting bulls, since such affairs are usually butting contests.

Man-caused mortality has accounted for 16 muskox, and possibly 24. Nine muskox were collected as specimens for institutions. Muskox capturing operations in 1964 resulted in two deaths. A cow was believed shot by Coast Guard personnel on Cape Mohican in 1964, and a bull and two cows were shot there in 1965. One bull was shot by a native on Cape Etolin in 1965. In addition, one cow was found on the edge of the bluffs a few miles east of Cape Mohican. The time of its death was estimated to have been close to that of the three muskox shot by the Coast Guard in 1965. In 1965, seven dead muskox were found and examined by Jerry Hout, of the U.S. Fish and Wildlife Service, on the landward side of the Bangookthleet Dunes. Although no positive evidence of killing by man was found, the circumstances of the mortality were unusual. The seven muskox were obviously a herd, consisting of an adult bull, two adult cows, two yearlings, and two calves. All were dead within the space of 100 yards, and they were lying in a straight line. Two were in shallow tundra ponds. The ages of the animals would argue against a natural death, except for possibly winter starvation. The spatial arrangement of the carcasses, the fact that there was an abundant food supply nearby, and the fact that no other similar mortality was recorded on the island argue against winter starvation. No form of accidental death was apparent at the site.

Weather may have some effects on muskox mortality. Nunivak Island has a relatively mild winter climate. Rain can fall in any month, and in winter can result in the formation of an ice crust over the vegetation. Similar conditions have been reported by Vibe (1954).

Also, sleet and rain in April and early May could adversely affect newborn calves by chilling and making them more prone to freezing.

Effects attributable to parasites and diseases have not been observed with Nunivak muskoxen. Parasites found in specimens collected on the island include an intestinal tapeworm (*Monezia* sp.), nematodes (*Trychostrongylus* sp.) in the abomasum, lungworm (*Dictyocaulus* sp.), and stomachworm (*Hemoncus* sp.) (USFWS Files, Bethel, Alaska). Tener (1965) presents a list of endoparasites recorded from Canadian muskoxen. He also notes one record of warble flies (*Oedemagena* sp.) in muskox. Muskox calves captured on the island and taken to the muskox farm at the University of Alaska in 1964 had warble fly infestation (Seim pers. comm.). It is not known to what extent warble flies attack muskoxen on Nunivak Island. The large reindeer herd on the island acts as a reservoir for infestation.

Table 4. Muskox mortality on Nunivak Island 1936 - 1966.

Year	Bulls	Cows	Imm.	Calves	Unknown	Total
1936			1			1
1945		1		1		2
1948	3	1		1		5
1949					1*	1
1950	2	1*	1			4
1951	1				1	2
1952					2*	2
1953	2	1				3
1954	2+2*					4
1955	1+1*	1			1	4
1956	3+2*	2*	1		1	9
1957	2*					2
1958					1	1
1959	4	1		1		6
1960	1				1	2
1961					3	3
1962	2	1	1		2	6
1963	6		1		2	9
1964	1	2		1	1	5
1965	3+1*	5	2+1*	2	2	16
1966	2+5*	2	1	1*	4+1*	16
	45	16	9	6	24	103

* Includes muskox remains found or recovered from animals which had died over a year before the remains were discovered.

REPRODUCTION.

There is not much information available on muskox reproduction. Work done by Tener (1954a, 1965) indicates that Canadian muskox cows give birth to calves in alternate years. He noted some exceptions to alternate year calving and the possibility of twining was recognized. Pedersen (1958) suggested that the variability in frequency of calving can probably be related to the nutritional condition of the cows. His observations indicated that a cow could have a calf every year under favorable conditions, and twins were not too rare. Improved reproductive performance of Thelon Game Sanctuary muskox when raised in captivity on a higher nutritional plane lends credibility to this hypothesis (Tener 1965). Observations on Nunivak Island and examination of calf percentages and herd growth rates (Tables 3 and 5) for the Nunivak population indicate many of the cows are having calves in successive years. The marginal existence of muskox at very high latitudes is not a problem on Nunivak Island where habitat conditions are quite favorable. Forage is green and growing for longer periods than on Canadian muskox ranges, and the carrying capacity of the range is higher. Quality and quantity of forage on Nunivak may be an important factor effecting the observed high calving frequencies.

Another factor which may improve reproductive performance on Nunivak Island is the confinement of the herd to a finite area and its influences on herd bull:cow ratios. There is always a surplus of bulls on the island, and although some herds are without bulls in early summer, most herds have acquired bulls by the breeding season. The restrictions on movement and wandering imposed by the island facilitate contact and possibly improve chances of successful breeding. Low reproductive rates of Canadian muskox may be partly attributable to failure of some cows to be bred.

Cows on Nunivak are breeding at three years of age and calving at four. Some three-year-old cows probably calve also. Studies of known-age animals or of reproductive tracts are required to determine this. Tener (1965) points out several instances of captive muskox giving birth to calves at two and three years of age.

Muskox breed in late July and August, giving birth to calves from mid-April to the end of May (Tener 1965). The gestation period is about 8 months. Teal (in Tener 1965) reports a gestation period of 246 days for a captive muskox. Palmer and Rouse (1935) reported the gestation period for a captive cow at 244 days. The earliest muskox birth recorded at the U.S. Biological Survey Experiment Station at College was on April 20, 1935. The latest was on June 24, 1934. Calving has not been directly observed on Nunivak Island, but Lensink (1966) reported seeing a newborn calf on April 5, 1966. The length of the calving period results in variable sizes of calves observed in summer. Differences in size are noticed in some yearlings also.

The sex ratio of muskox at birth is unknown. Teal (1965 pers. comm.) captured 52 different calves on Nunivak in 1964. Only 14 of these were females. This would result in a sex ratio of 271 males : 100 females, or about 3 : 1 if the sample (one-half of the calves in the population) was representative of the population, and if such a ratio occurred every year. A bias in favor of male calves is possible if they are more susceptible to capture. Of muskox calves born at the experiment station at College in 1934 and 1935 which survived to 1936, 3 were females and 12 were males, a ratio which tends to substantiate Teal's findings. If a 3:1 ratio in favor of males exists at birth, it could have important implications in the management of the population. It is interesting to note that of 61 recorded mortalities of adult muskox, 45 were males and only 16 were females (Table 4).

There have been no confirmed cases of twining on Nunivak Island, although there have been numerous sightings of two calves with one cow. Such sightings probably reflect loose association between calf and cow, where calves often attach to different members of a herd. Palmer and Rouse (1935) reported cows to be without a highly developed maternal instinct.

BEHAVIOR.

Notes on behavior were made when the opportunities arose, although such observations were incidental to other studies. These observations follow below.

Defense.

Perhaps the best known and most characteristic behavioral trait exhibited by muskox is that of forming a defensive circle when danger threatens. On numerous occasions I observed this grouping movement. Often it was initiated by a nasal snort produced by one or more of the alarmed animals. At the sound of the snort all muskox in a herd would immediately rush to a common gathering point and face the danger. The entire group would face the disturbance unless the danger threatened from several sides, whereupon a circular formation was made. Stability of the formation varied with the terrain and the degree of disturbance. When cornered by terrain features the group would hold fast, and individuals would charge if approached too closely. On most occasions muskox ran at my approach. Once the muskox started to run, they would often run for considerable distances of up to several miles. At other times, just running out of sight was sufficient, and the herd could be found on the other side of a hill or ridge looking back. Often, if not pressed or if the disturbance was discontinued, the herd would return to the activity which had occupied it before it became alarmed. It is probable that the herd defense formation is instinctive. The herds on Nunivak Island exhibit this behavior even though they have not experienced wolf predation since introduction. The herd defense is of value against natural predators but makes the muskox quite vulnerable to man.

Solitary bulls were much less prone to flight than herds. Characteristically, bulls would exhibit uneasiness and agitation at my approach by rubbing the side of their heads on their forelegs and horning the ground and nearby vegetation. If approached closer than 100 ft, bulls would snort if a charge or flight was imminent. During the period of the rut, bulls become belligerent and should not be approached too closely. On July 18, 1965, I was charged by an adult bull after I approached to within 50 ft while photographing the animal. The bull charged to within 25 ft, paused, then charged to within 4 ft before stopping abruptly, snorting, and running off. I believe this bull mistook me for another bull, and it was not until he approached closely that he identified me as a human.

In July 1966, Jerry Hout, of the U.S. Fish and Wildlife Service, was charged first by a bull and then by a cow as he was trying to photograph a small herd on a small island north of Abaramiut. The herd was repeatedly cornered and closely approached when both charges took place. In both instances the charges were halted by throwing rocks at the heads of the muskox.

Soon after introduction, there were a few reports of muskox chasing people on the island. These reports by Eskimos were probably exaggerated accounts of close approaches by friendly, half-domesticated muskox used to the presence of people. Also at that time, dogs were allowed to run loose in the villages, and several dogs were gored by muskox. In a few instances, muskox chased dogs into the villages.

Intraspecific Interaction.

On several occasions I saw old cows leading herds. This behavior is common to many ungulate groups. Frequently I observed muskox display dominating behavior to younger animals. On July 1, 1965, I saw a yearling chase a feeding calf away from a willow and then begin to feed there, and on July 5th I saw a yearling displace a smaller yearling from a feeding site. Several times I have seen adult bulls follow and sometimes chase other members of the herd, usually subadult bulls. On July 4, 1965, a herd bull chased a cow for several minutes, then went back to feeding.

Bulls are restless and aggressive during the rut. Immature bulls are tolerated in the herds, although interaction with herd bulls takes place. I have seen subadult bulls head-butting and pushing with adult bulls, but such contests were not serious. Several times I have seen adult bulls fight, but these affairs were not concerned with the possession of a herd. One such case involved occupancy of a snowbank, where the first occupant was evicted by a second bull after two head-on clashes. During the summer, most bulls are solitary or are part of mixed sex and age herds. When bulls come together at such times, they often exhibit antagonism toward each other. One unusual group of five adult bulls observed on Cape Mendenhall in late June was constantly showing the instability of such an association. The bulls were repeatedly horning the ground and charging each other. Disturbance by natives in the area had probably led to this temporary association.

When bulls fight, they face each other and begin backing apart, swinging their heads from side to side to display their horns. After reaching a distance of 10-30 ft they charge at a fast pace and meet head-on with the boss of their horns. This procedure is repeated until one or both lose interest, or one takes flight.

Fighting between bulls was often observed when muskox were approached by aircraft. Such fighting reactions were probably displacement activity between attack and escape drives (Tener 1965). Similar displacement activity was seen only once when muskox were approached on the ground. On June 21, 1966, two bulls took flight following disturbance and began to fight. Alternate fighting and running continued for about 15 minutes.

Play.

Tener (1965) noted that play among muskox was unusual. I found many instances of play among Nunivak muskox. Playing was generally limited to calves and sometimes yearlings. Calves would often chase each other in the vicinity of the herd and engage in butting and pushing contests. Yearlings also participated in such activity. On July 19, 1965, a herd of 14 muskox was observed running for 7 minutes with different individuals running in different directions, for no apparent reason. The herd had been peacefully grazing before running began, and it went back to grazing when running abruptly ceased. I believe this was play activity.

Miscellaneous.

Tener (1965) reports that Canadian muskox dig pits or wallows in friable soil or sand. I found many muskox rubbing sites in sand dune areas and on sides of peat mounds. The only observed use of these areas was that of rubbing the sides and rear of an animal. Much rubbed-off underwool was present at such sites.

On several occasions I saw muskox use snow patches to lie on in summer. Hall (1964) reports similar behavior. I believe the cool snow patches are used to avoid insect pests. During early July 1965, I observed muskox rubbing their heads in willows, lying on snowbanks, and even sitting in rivers to avoid insects. Snowbanks may also be used to cool off on hot days.

Herds are gregarious and feed and act as a unit. In feeding, the animals remain fairly close to each other. If a herd is moving, individuals left behind will run to catch up when they discover their outlying position. The herd feeds and rests together. The limited observations I made suggest alternate feeding and resting periods of from .5 to 1.5 hours in duration. When resting, individuals of the same age class often rest together. This was more noticeable with calves.

The literature makes little mention of muskox vocal sounds. In addition to the nasal snort of alarm, muskox also make a mooing type of sound which is similar to that of cattle. I heard this on only two occasions on the island. At the muskox farm at the University of Alaska, the muskox frequently moo.

THE POPULATION.

Size and Composition.

Muskox are gregarious animals that are usually found in herds. Solitary adult bulls in summer are an important exception. Herd size and composition are relatively constant at any one time of year, but both change seasonally to a marked degree.

The composition of muskox herds encountered during the study was recorded whenever conditions of identification of all individuals in a group were favorable. Table 5 presents a summarization of composition data for muskox herds classified during the summers of 1965 and 1966. A breakdown of the individual observations is given in Appendix B. The data represent both ground and aerial observations, though most of the counts were made from the ground. Sexes could be distinguished with certainty only among adults, where conspicuous differences in horn size and boss development exist. The subadult group presented some difficulties in classification due to differences in rates of horn development and sexual maturation between sexes. Tener (1965) has gone into the ontogenesis of horns of muskox. By 6 months of age, calves develop a white forelock which becomes very distinctive in yearlings and then diminishes in whiteness as the animal matures. Horn development through the yearling stage is roughly similar between sexes, but by the time the animals are two years old differences in the appearance of horns can be detected. Most apparent is the deflection of the horns from the horizontal, greater in females than in males. The horns of each sex differ also in size and in the degree of dorsoventral flattening. Those of the cow are smaller and more flattened. All two-year-olds were classed as subadults. By the age of three years, the cow's horns, although not as large as the bull's, have reached their maximum deflection. Three-year-old cows have the appearance of adult cows except for the juvenile white forelock which is still apparent. Three-year-old cows were classed as adults because of their similarity to adults and because they are thought to breed at three years of age. At the age of three years, bulls still have the horizontal aspect of horn growth and so differ considerably from adult bulls. Three-year-old bulls were classed as subadults. By four years of age, bulls have achieved maximum deflection of their horns and have the appearance of adults except for the fading white hair on their forehead, which at four years is of a tan color. Four-year-old bulls were classed as adults. At five years of age the color of the forehead has turned to the grey or grey-brown color of the adults.

The largest herds were found in winter (Table 4). Tener (1965) has also reported larger herds on the average in winter. Large groups in winter result from the combination of smaller associations and by the attachment of solitary bulls to the groups. During a March, 1966, survey of Nunivak herds, all muskox were found in groups of three or more animals except for a single adult bull. Herds numbering up to nine animals composed of bulls only were seen in several areas. Such groups occurred most frequently in regions which are occupied primarily by solitary bulls in summer, such as the north and northeast coasts of the island. In other areas, occupied by herds and solitary bulls in summer, the bulls join the herds in winter. The largest herds seen were a group of 37 on Cape Mendenhall and one of 35 on Cape Mohican. Both of these regions are winter concentration areas where the close proximity of many moderate sized herds is conducive to the formation of large groups. Five of the herds seen in March contained 20 or more muskox. The average winter herd size was 11.

With the arrival of spring, the muskox disperse from winter concentration areas, and the herds become smaller. Many of the adult bulls separate and become solitary as the summer progresses. The reasons for this separation are not clear but probably involve a progressive intolerance of bulls for others due to hormonal changes (Tener 1965). Loss of reproductive vigor by old bulls may cause them to lose interest in other muskox. Up until late June herds may have two or more adult bulls, especially the larger associations of 12-20 individuals. Such cases are probably remains of winter herds that have not fractured and/or instances of pre-rut tolerances between bulls. With the onset of the breeding season, intolerance between bulls leads to ejection of subdominant bulls from the herds. Almost all herds classified during the latter part of July and during August had only one adult bull (Appendix B). Some of the displaced bulls join herds which have no bulls. In 1966, four out of 12 mixed sex and age herds were observed without bulls before early July. After mid-July, all herds seen had bulls (Appendix B). Some herds may possibly go through the breeding season without a bull. During August 10-11, 1965, two herds were observed each with four muskox and without bulls.

Bulls not with herds are usually solitary, but may join with others to form pairs, rarely more. The largest group of bulls seen was that of five bulls on Cape Mendenhall on June 27, 1966. This association was probably a result of disturbance by beachcombing natives. The bulls in this group exhibited considerable antagonism towards one another, and it is doubtful that these animals remained together for more than a day or two.

Summer herds are smaller than winter herds, averaging 8 muskox per herd when only groups of two or more are considered (Table 4). Only two herds larger than 20 were seen during the summers of 1965 and 1966. These contained 27 and 24 individuals, respectively.

With the termination of the breeding season and the advent of winter, the herds return to the wintering areas and combine into larger herds. Solitary bulls combine into groups exclusively of bulls or join mixed sex and age herds.

Summer herds are relatively more discrete units than winter aggregations, although some intermingling and changing of herd groupings takes place in the summer. Winter herds are in closer contact, resulting in merging and fracturing herds, with different combinations of individuals formed. When the herds disperse in the spring, they have undergone mixing so that the composition of groups changes from year to year. Such mixing is suggested in the composition of several of the herds that were classified, where the number of yearlings exceeds the number of cows in the herd (Appendix B). One herd was composed of three yearlings and two subadults, and another of two subadults and three adult bulls. Mixing of herds in winter and early spring has biological advantages in that it provides for greater genetic recombination.

Tener (1965) reports never having seen individuals other than adult bulls wandering alone, nor herds composed solely of immature animals. The herd of yearlings and subadults mentioned above is an example of the latter. Although groups of immatures are rare, they do occur on Nunivak Island. Two solitary cows were seen in 1966. One was seen on Iloodak Point, on the western north coast of the island, on June 6. The other was seen near Dooksook Lagoon on August 15. Both were several miles from any other muskox and appeared in good health.

Composition percentages differ between the two years. In 1965 only the composition of mixed sex and age herds was recorded. In 1966, an attempt was made to classify all muskox seen, groups as well as lone animals, in order to be able to estimate all classes in the total population. I believe the data presented in Table 6 give a good estimation of the composition of the muskox population. When applied to the 1966 aerial survey counts, the results are in good agreement. For example, if the 8% solitary bull percentage is applied to the 569 muskox counted during the survey, the estimate of 45 is the same as the 45 actually counted. Apparently the percentage of solitary bulls has remained relatively constant for the past few years. Percentages of solitary bulls observed during aerial censuses in 1962, 1963, 1964, and 1965 were 8, 8, 7, and 8, respectively. Tener (1965) found summer solitary bull percentages ranging from 3.9 to 7.9. Calves formed 21% of muskox classified in 1966. If 21% is taken of the 569 total, the resultant 119 calves is higher than the 110 calves counted, but the discrepancy of 11 can possibly be attributed to low counts of calves during the survey. Calves are difficult to count from the air when they are in large herds, where they hide among and under the often closely appressed adults. The observed calf percentage for the 1966 survey was 19, whereas in 1965 calves formed 21% of the population, a figure that agrees with the 1966 estimate of 21%. Calf:adult cow ratios were similar for 1965 and 1966, with ratios of 83:100 and 85:100, respectively. This is the minimum ratio since three-year-old cows were included in the adult cow counts, although they may not calve at that age. Herd ratios of adult bulls to adult cows were 38:100 and 45:100, respectively. Yearlings composed 17% of classified muskoxen. This is equal to 95 yearlings of the 569 muskox counted in 1966. If the

10 calves removed by John Teal, Project Supervisor, Muskox Project, University of Alaska, in the fall of 1965 and the one known yearling mortality in the spring of 1966 are added to the 95 yearlings, the sum of 106 corresponds fairly well with the 110 calves counted in 1965.

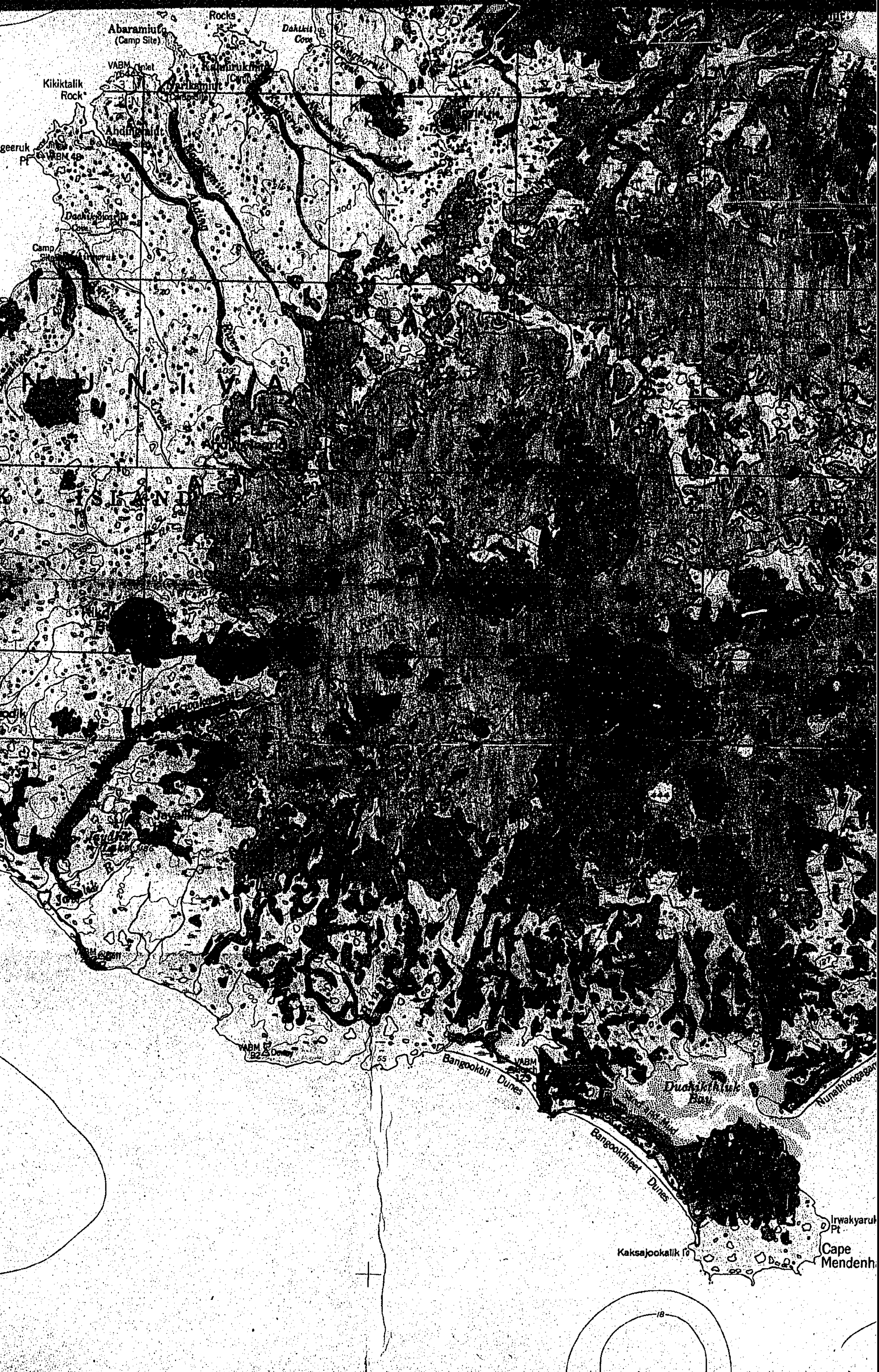
If the proportion of bulls, solitary or in groups, classified in 1966 is applied to the 1965 composition data and the latter is then extrapolated to the 1965 survey results, as was done with the 1966 data, similar estimates can be made. The extrapolated calf estimate for 1965 would be 23% or 116 calves, which agrees well with the 110 calves counted. The estimate for yearlings would be 74. If the 23 calves removed by John Teal in 1964 are added to this estimate, the resultant 97 compares closely to the 102 calves actually counted in 1964.


Ikookstaksvak Cove
Light
Cape Mohican
Ikooksmiut (Camp Site)
Nabangoyak Rock
Datheekook Pt
BASE LINE
Kigoumiut (Camp Site)
Iloodak Pt
Binakslit Bluff
Cape Algonquin
Nash Harbor
Landing Area
Chingeeruk Pt
Kikiktalik Rock
Abaramiut (Camp Site)
VABM
Camp Site
Tachyhuiniut
NUNIVAK ISLAND


Cape
Etolin
Cabins
VABM
82
Etolin Bay
Ooklik
Dunes
Mekoryuk
Nabakyalik
Pt
Kangnaksnak
Pt
Nabakyalik Pt
Arwirnuk
Rock
Kikartik
Rock
Ahkitook
(Camp Site)
Oronikowaktalik
Rock
Ahnowiksat
Rocks
Kikoojit
Rocks
Dahtkit
Cove
Abaramiut
(Camp Site)
Kikiktalik
Rock
Chingeeruk
Pt
Cape Algonquin
Nash
Harbor
84
66
54
60
72


Cape Etolin
Cabins
VABM 82
Etolin Bay
Ooklik Dunes
Mekoryuk
Nabakyalik Pt
Kangnaksnak Pt
Jingeeruk Pt
Kookijilik Pt
Dunulimjingia Pt
Triangle Island
Kikartamjingia Pt
Ikathleewimjingia Pt
Ikathleewik Bay
Cape Manning
Nooravloaksmiut Island
Leroy
Kanikyakstalikmiut
(Camp Site)
Ahmikdoligamiut
(Camp Site)
Little Cape Corwin
Cape Corwin


Rocks
Abaramiut
(Camp Site)
Kikiktalik
Rock
Chingeeruk
Pt
Cape Algonquin
Nash
Harbor
Binakslit
Bluff
Kigoumiut
(Camp Site)
Illoodak Pt
Landing Area
Cape
Mohican
Light
Nabangoyak
Rock
Datheekook
Pt
BASE LINE
ISLAND
72
60
30
24
12
54
42
30
60
30


Rocks
Abaramiut
(Camp Site)
Dahkkit
Cove
VABM
Kikiktalik
Rock
Camp
300
VABM
55
Bangookbit Dunes
VABM
Bangookthleet Dunes
Kaksajookalik
Pt
Cape
18


Kikartamjingia Pt
Ikathleewimjingia Pt
Ikathleewik Bay
Cape Manning
Nooravloaksmiut Island
Leroy
Kanikyakstalikmiut (Camp Site)
Ahmikdoligamiut (Camp Site)
Little Cape Corwin
Cape Corwin
Nakooytoolekmiut (Site)
Oongalambingoi Dunes
Nunathloogagamiutbingoi Dunes
Dunes
Irwakyaruk Pt
Cape Mendenhall
60

Table 5. Summer and winter muskox herd sizes.

Summer 1965 & 1966		Winter 1965/66	
Size of Herd	No. Seen	Size of Herd	No. Seen
1	84	1	1
2	14	3	4
3	3	4	1
4	6	5	4
5	17	6	6
6	12	7	1
7	13	8	1
8	16	9	4
9	11	10	3
10	4	11	1
11	5	12	2
12	7	13	1
13	3	14	2
14	4	18	1
15	3	20	2
17	3	26	1
19	2	35	1
24	1	37	1
27	1		
Average herd size for groups larger than 1 was 8		Average herd size for groups larger than 1 was 11	

Table 6. Composition of muskox herds classified during the summers of 1965 and 1966.**

	1965	1966
Solitary adult bulls	19*	25
Percentage solitary adult bulls	8*	8
Adult bulls, solitary or in groups	39*	52
Adult bulls in mixed sex and age herds	26	37
Total adult bulls	65*	89
Percentage adult bulls	26*	26
Adult cows	69	84
Percentage adult cows	28*	25
Population ratio, adult bulls to adult cows	94:100*	106:100
Herd ratio, adult bulls to adult cows	38:100	45:100
Calves	57	71
Percentage calves	23*	21
Ratio, calves to adult cows	83:100	85:100
Yearlings	36	56
Percentage yearlings	14*	17
Subadults	23	35
Percentage subadults	9*	10
No. of herds	28	30
No. of observations	28	68
Total no. in herds	211	284
Total no. of muskox	211 (250*)	336

* Figures extrapolated from more complete 1966 composition data.

** A breakdown of the individual observations is given in Appendix B.

Distribution.

Muskox distribution on the island is determined largely by the seasonal differences in habitat conditions which affect movement and range occupancy. Since the time of their introduction, large areas of the island have received little or no use, while other areas such as Cape Mohican and the Cape Mendenhall sand dunes have always been favored locations. Palmer and Rouse (1945) noted that the muskox were confined to the dry tundra range at the west end of the island and to the sand dune type, and that wet tundra areas were avoided. Soon after their introduction, Palmer (1938) reported a group of muskox on Twin Mountain. Muskox have been seen regularly in that area ever since. The number of muskox in the Twin Mountain-Cape Corwin region has increased considerably since 1960. The area has become a major summer range with a large number of herds seen there in 1964-1966.

Areas of the island avoided by most muskox are primarily the predominantly wet tundra areas from Nash Harbor to Mekoryuk (Fig. 3) and the central interior areas. The northeast portion of the island from Cape Manning to Twin Mountain does not receive as much use as western and southern areas.

Distribution of muskox differs considerably between summer and winter (Fig. 3). In winter, muskox are concentrated along the coast of the island, along the northwestern bluffs and southern sand dunes. Winter surveys conducted by Fish and Wildlife Service personnel in 1959 and 1963 showed highest concentrations of muskox in the Cape Mohican and Cape Mendenhall areas. None were observed in the interior of the island. The March, 1966, survey by the writer showed most muskox to be within 1 mile of the coast. One herd was found on Muskox Mountain and has apparently been in the area for many years, according to natives. The largest number of herds was seen along the dunes from Cape Corwin to the Bangookbit Dunes. Another large concentration was seen on the northwestern bluffs, from Mikisagimiut to Dooksook Lagoon. Smaller groupings were seen on the coast near the Jayalik River and on the north coast between Ahdingamiut and Kamirukmiut.

In winter, muskox tend to occupy points and projections of the coast. Small islands near the coast are occupied to such an extent that muskox have been stranded on these islands when the sea ice melts. During the summer of 1966, a herd of five muskox was stranded on two small islands between which they could cross, near Abaramiut. Triangle Island, off the northeast corner of Nunivak has had muskox stranded on it in the past. Three muskox were reported there in the summer of 1938 (Palmer 1938), and two were stranded there in 1964 (USFWS, 1964). In 1957 two bulls were seen on an island south of Cape Corwin (USFWS Files, Bethel, Alaska). Muskox which have been stranded on islands have spent the summer on them with no reported ill effects.

In the summer muskox are much more widely distributed. They are largely absent from the immediate coast except for the northwestern bluff areas which are occupied all year to some extent. Early summer and midsummer distribution centers along stream valleys up to about 15 miles inland (Fig. 3). In late summer the muskox become more scattered as they move out on the tundra. Summer distribution

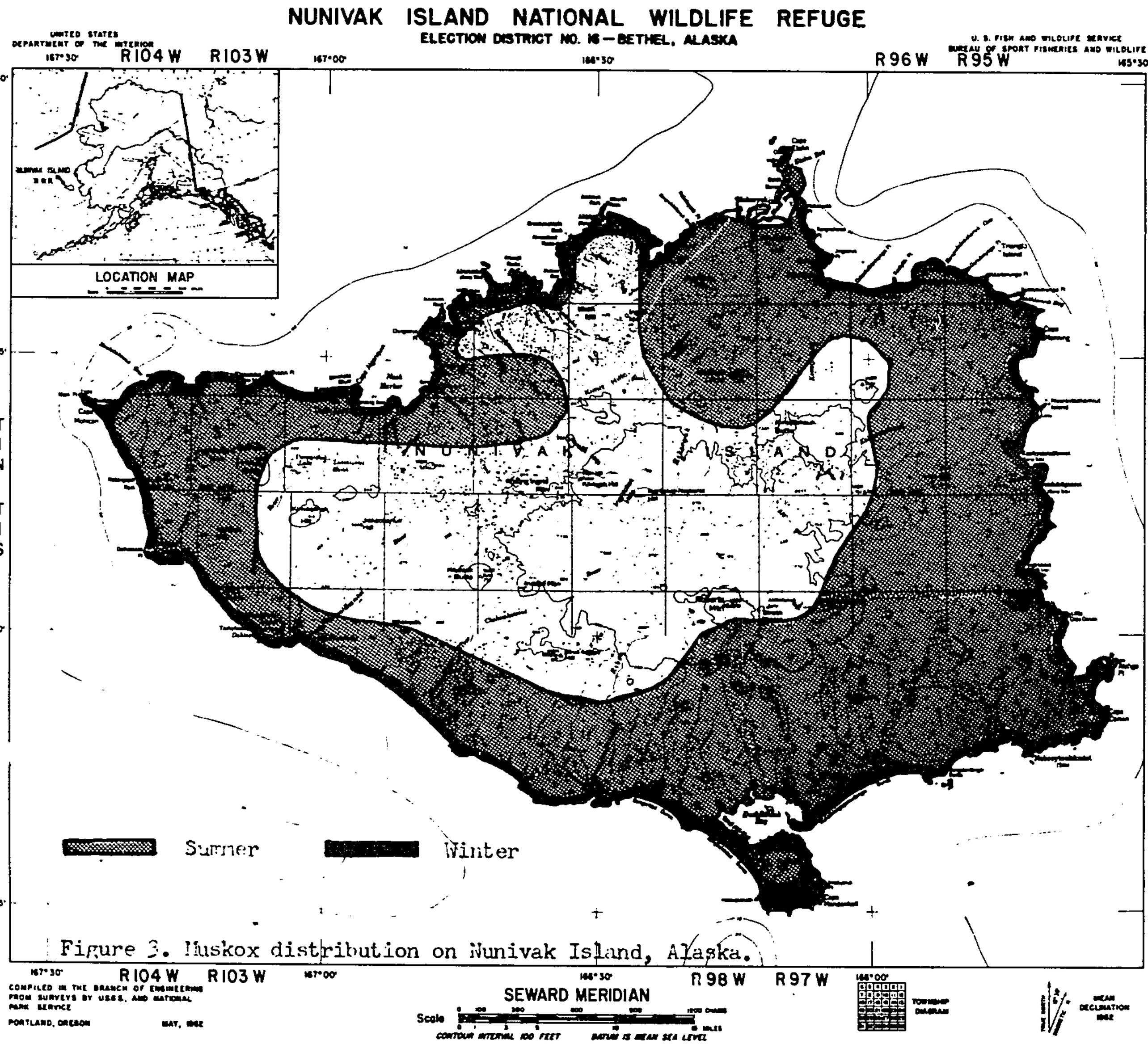


Figure 3. Muskox distribution on Nunivak Island, Alaska.

corresponds to inland extensions of the winter distribution pattern. Northcentral and northeast interior areas have the fewest muskox while the northwest-southwest and the southeast areas have the most.

Movements.

Muskox movements are determined largely by the use made of feeding areas. Tener (1954a) reported seasonal movements of up to 100 miles on the Canadian mainland and movements generally less than 50 miles on the artic islands. Seasonal movements on Nunivak Island are much more restricted because winter and summer ranges are located close to each other. Muskox do not migrate. Seasonal movements on Nunivak involve gradual shifts between ranges when summer and winter ranges are separated as in the southern part of the island. In the Cape Mohican area the same range is used in both winter and summer.

Mobility of muskox is much lower in winter than in summer, with most of the animals remaining adjacent to the coastline. Movements of herds are restricted, with the animals feeding in one place for several days or longer. One herd remained on a small 0.5 acre island off Atahgo Point for a period of at least 17 days, from March 19 to April 5, 1966. Tracks, droppings, and other sign observed during March indicated muskox were using coastal dune and point areas almost exclusively, and were not venturing inland to any extent. Signs of activity on Cape Mohican indicated the large herd there had occupied that relatively small area for a major portion of the winter. Tener (1965) also noted low rates of movement of Canadian muskox in winter.

Muskox herds disperse in spring and increase their movements greatly. The herds generally leave the coastal wintering areas and move into and along stream drainages in early summer, moving inland as much as 15 or 20 miles. In late summer the herds move away from stream valleys and out onto the tundra. During the course of the summer the herds cover most of the island except for the central interior portion of the island which is rarely occupied. Summer muskox movements are related to use of different range types which is discussed in the section on range use.

In the summer, muskox commonly travel 2-3 miles in a day. Hall (1964) noted the extensive movements in and out of valleys in Greenland. Movement of herds has caused some problems in the muskox surveys when the census period has been protracted because of adverse weather. In 1951, one herd moved 7 miles in a 2 day period (USFWS Files, Bethel, Alaska).

Solitary bulls also wander extensively. Some bulls were observed to remain in restricted areas for extended periods of time. These appeared to be old animals, and it is suspected that senile bulls that have lost their reproductive vigor are much less prone to wandering. Such individuals often remain in wintering areas after other muskox have left.

RANGE RELATIONSHIPS.

Quantitative Food Consumption.

Little work has been done concerning the amount of forage required to maintain a muskox. Studies at the U.S. Biological Survey Experiment Station at College during 1930-1936 indicate muskox require 18-20 lbs of air dry forage per 1,000 lbs of animal per day, or about 2 lbs/100 lbs per day (Palmer and Rouse 1935). This is similar to maintenance requirements of sheep (3 lbs/100 lbs per day) and cattle (2 lbs/100 lbs per day) listed by Stoddart and Smith (1955).

Food and Habitat Preferences.

Several authors have presented lists of plant species utilized by muskox (Banfield 1951, Palmer 1944, Palmer and Rouse 1935, Tener 1954a, 1954b). Food species vary with the season and the terrain. In summer, muskox browse or graze on willows, grasses, and sedges along streams, while in winter, sedges and grasses on ridges and hills become relatively more important. Tener (1965) working on several Canadian muskox ranges found summer ranges to be centered around streams with willows (primarily *Salix alaxensis*, but also *S. Richardsoni* and *S. arbusculoides*) and a number of sedges, grasses, and forbs taken. During winter he found muskox concentrated in elevated areas with shallow snow depth, feeding on windblown slopes, taking *Ledum decumbens*, *Empetrum nigrum* and other browse species, grasses, and sedges. Palmer (1944) and Palmer and Rouse (1935) recorded the forage used at the experiment station. Several browse species preferred there such as *Populus* spp. and *Alnus* sp. are not found on most muskox ranges including Nunivak Island. Genera of grasses taken include *Agropyron*, *Calamagrostis*, *Festuca*, *Glyceria*, *Hierechloe*, *Phleum*, and *Poa*.

There are few observations of forage species taken on Nunivak Island by muskox. Rouse (1948) noted prostrate browse species were of greatest importance in winter with some grasses also taken. Use of

Elymus mollis, *Angelica lucida*, and *Rumex* spp. has been recorded (USFWS Files, Bethel, Alaska). Late winter stomach contents of a bull collected on a "heath type" contained *Empetrum nigrum*, *Betula nana exilis*, *Salix* sp., *Sphagnum* sp., and unidentified grasses and sedges (USFWS Files, Bethel, Alaska).

Observations made during this study showed definite seasonal habitat preferences similar to those found by Tener (1965). Forage preferences influence choice of range types to a greater extent in summer when forage is most abundant, of greater palatability, and when muskox are most mobile, rather than in winter when availability is more of a problem.

The most important summer range type is the grass-browse type. Both the grass hummock and the riparian grass-browse subtypes of this type have very rapid annual vegetative growth, and the lush new vegetation attracts most of the muskox use in the summer. After departing from their winter ranges, the muskox move to the riparian zones along streams. Many of the herds utilize this subtype until mid-July or later. Most important of the species used at this time is the preferred *Salix pulchra*. Use of this willow is evident on many of the stands on the island. Muskox feed on this willow by stripping the leaves off the terminal twigs, giving the willows a ragged appearance (Fig. 4). This appearance and the patches of wool that are rubbed off as the animals move among the willows are indicators of muskox use long after the muskox have moved to other areas. *S. alaxensis* is also used, but its more limited distribution on the island makes it less important.

Figure 4. Salix alaxensis and S. pulchra on the Ingrimiut River showing effects of use by muskox (July 6, 1966).

Figure 5. Appearance of muskox winter feeding crater in early June (June 14, 1966).

It appears to be less palatable than S. pulchra. Prostrate willows, chiefly S. reticulata and S. ovalifolia are also used in the riparian subtype. In addition to the willows, heavy use is received by Calamagrostis canadensis and associated species including Festuca spp., Alopecurus alpinus, Carex spp., Equisetum arvense, and Rubus spp.

Muskox on the western end of the island move to the grass hummock subtype from the winter areas on the edge of the bluffs, but also make use of wet tundra sedges (primarily Carex aquatilis), especially where new sedge growth is available, as along the edge of standing water or in reindeer trample sites, described in a following section. The riparian subtype on the western end of the island lacks shrub willows and does not have the floral diversity of other riparian areas on the island. Muskox on the west end use riparian areas, but not to the extent that they do in the Twin Mountain area, for example. Consequently, more use is made of the grass hummock subtype on the west end, especially the Calamagrostis fringe pockets bordering wet tundra areas and along the bluffs. Grasses and sedges are hence relatively more important summer foods on the western portion of the island.

In late July and August, the muskox begin to make greater use of the grass hummock subtype over much of the island. Muskox move away from the streamside areas and seek out patches of grass hummock which occur as pockets in the dry tundra type as well as in extensive tracts. Species eaten are similar to the riparian species as the subtypes have many species in common. Over much of the eastern half of the island Salix pulchra grows among the grass hummocks and continues to receive much use. Other preferred species include Angelica lucida, Arctagrostis latifolia, Calamagrostis canadensis, and Poa spp.

Summer use is not confined to the grass-browse type. Use of Carex aquatilis in wet tundra areas has been mentioned. Muskox move extensively in the summer, and they feed in dry tundra and alpine tundra areas when they traverse them in moving between grass-browse areas. On dry tundra and alpine tundra muskox take Arctostaphylos alpina, Empetrum nigrum, Betula nana exilis, Carex bigelowii, Dryas octopetala, Hierechloe alpina, and Salix arctica. Use is directed to new growth.

A few muskox remain on the sand dunes during the summer, usually solitary bulls. They use primarily Elymus mollis and associated species such as Arenaria peploides, Lathyrus maritimus, Festuca rubra and Poa spp. Green sedges and grasses and prostrate willows around dune ponds, and tidal wetland sedges also receive use.

On July 20, 1966, I examined two islands north of Abaramiut which had been occupied by five muskox since breakup of the ice around the island. The islands, together only a few acres in size, were vegetated primarily by wet tundra species. Carex aquatilis, Eriophorum angustifolium, Sedum roseum, mosses, and a few small patches of Empetrum nigrum made up most of the cover. Elymus mollis grew around the edges of the islands, covering about 20% of the larger island. Use was evident over both islands with utilization estimated at about 30%. Both islands had received considerable winter use in past years, resulting in patches of moss and bare peat, with small Empetrum remnants left. Invading Carex glareosa, Luzula sp., and Sedum roseum appeared to have been avoided. Of the species used on the island during the summer, *Elymus* had received the most use. *Carex aquatilis* and *Eriophorum angustifolium* were taken heavily, particularly where dampness or standing water resulted in green growth. *Eriophorum scheuchzeri* was taken where it occurred, but it was present in only limited quantities. *Ligusticum hulteni* and *Angelica lucida* were also eaten.

Winter muskox range is confined for the most part to the very perimeter of the island, along the northwestern bluffs or the southern sand dunes. Muskox winter range is selected more on the basis of its exposure to winds and the windswept feeding areas they provide than on the basis of forage species present. The apparent desire to locate on vantage points with good views of surrounding terrain may also influence the occupation of coastal high points and projections. Movement of muskox is much reduced from that of summer. Herds remain in small areas for several days or even weeks. Feeding is done in small craters pawed from the snow which is usually less than one ft in depth, with animals feeding individually. Under such conditions, the muskox feed on what is available in the crater, although selection for browse species takes place. Muskox wintering on the coast are found in two range types almost exclusively. On the northwestern bluff areas, wintering herds use the wet tundra type. Along the southern coast muskox are primarily on the beach grass-forb type. These types are the dominant range types in these areas. One herd wintering on Muskox Mountain south of Mekoryuk uses alpine and some dry tundra vegetation during the winter.

Muskox wintering areas were visited in late winter and again in early summer while locations of feeding craters were still obvious in the vegetation (Fig. 5). Feeding craters were easily located by their close-cropped appearance and presence of pellet groups, and species that had been eaten could be recorded.

Muskox wintering areas near Nariksmiut, on Cape Mohican, near Dooksook Lagoon, and near Dahloongamiut Lagoon were examined. Feeding craters averaged about 3 ft in diameter. Vegetation was cropped down to variable levels, usually to the moss layer or 2-3 inches above the ground surface. The primary species taken was Carex aquatilis. Other species taken included Eriophorum angustifolium, Luzula sp., Moss (Hylocomium sp. and Sphagnum sp.), Petasites frigidus, Rubus chamaemorus, and Salix sp. Some feeding craters were located on grass hummock pockets and on dry tundra along the bluffs. At such sites plants taken included Empetrum nigrum, Arctagrostis latifolia, Calamagrostis canadensis, Poa sp., Trisetum sibiricum, and moss.

On sand dunes, muskox use was concentrated on Elymus mollis. On the drier landward sides of the dunes heavy use was also made of Empetrum nigrum. Summer observations indicated that the mixed Empetrum-Elymus transition vegetation on the dunes is preferred to pure Elymus stands in winter. In addition to the above species, Betula nana exilis, Festuca rubra, moss, and some lichens were taken. Use of browse species reflects their palatability to muskox in winter.

The herd on Muskox Mountain wintered primarily on alpine tundra. Most feeding was done on Empetrum nigrum. Other species taken include Salix reticulata, Carex spp., Dryas octopetala, Loiseleuria procumbens, and moss.

Empetrum nigrum appeared to be taken readily wherever it was available. Most noticeable use on this species was found on small islands adjacent to the coast. One small island near Atahgo Point on the southeast corner of the island was observed to have muskox on it in March and was examined the following summer. Very heavy use of the island had reduced the vegetative cover or removed it altogether in areas not protected by deep snow. Elymus and Empetrum were hardest hit, but Festuca rubra, Salix arctica, Carex bigelowii, and Trisetum sibiricum were also taken in quantity. Some species such as Luzula nivalis, Cornus europea, Cnidium ajanense, and Ligusticum multelinoides seemed to have been avoided, especially Luzula.

In spring, the muskox in sand dune areas feed almost exclusively on the new sprouts of Elymus until early June when they begin to disperse to summer ranges. Muskox on wet tundra bluff areas may feed in previous year's grass hummock vegetation before new green growth is available.

Use in Summer.

In summer, muskox are constantly moving up and down river systems and across the tundra between drainages. They do not feed intensively in one spot. Herds do not usually remain at one site for longer than one or two days. Use of the vegetation is quite light and comes at a time when maximum growth is occurring.

The greatest effects of summer use are felt by the shrub willows. Foliage removed from willows is not renewed within the same growing season, and if defoliation occurs in consecutive years some of the willows may be killed. Moderate cropping of willows serves to stimulate increased lateral growth and so may increase vegetative production. Some willow stands showing excessive use were found (Fig. 4). Generally, however, use of willows was light to moderate. Willows in the northeast corner of the island receive little use.

Use in Winter.

Winter use is much more localized and intensive in nature. Herds may feed in one location for several days or longer, and remain in the vicinity of favorable sites for long periods. Winter feeding results in the close cropping of vegetation in feeding craters pawed in the snow. Examination and clipping studies of several such craters in the wet tundra sedges indicated an average of about 35-50 percent of the vegetation by weight was taken. In addition, some vegetation is pawed or trampled in the process. Where use is on *Elymus* in the sand dune areas or on *Carex* sp. in wet tundra areas, recovery of the vegetation in the craters during the following growing season is usually very good. Where browse species are taken on alpine and dry tundra, or on drier sand dune areas, and on small islands, recovery is much slower. *Empetrum nigrum* is especially susceptible to damage from browsing or trampling in winter. When the leaves are broken or eaten off in winter, the affected portion of the plant dies. Recovery of *Empetrum* and other browse species in feeding craters may take several years. Repeated winter use of such areas leads to deterioration of range quality. This deterioration was evident on Muskox Mountain and western bluff dry tundra areas, although reindeer could have contributed to the problem in these areas. The most outstanding examples of range overuse by muskox are found on the small islands adjacent to Nunivak Island. Winter use of these islands for many years has greatly reduced the vegetative cover and has changed the dominant plant cover species. The original *Empetrum* cover of several of these islands has been killed out and replaced by mosses and sedges or these areas have remained bare. A small one-half acre island occupied for at least 17 days by about 20 muskox during late winter was examined the following summer. Utilization of all forage on about one-fourth of the island was as high as 90-95%, and was about 50-70% for the remainder of the island. The vegetation in a narrow strip around the edge of the island was protected by deep snow. One portion was completely denuded of vegetation (Figs. 6 & 7). *Elymus* rhizomes had resprouted to form the only vegetation on the denuded area. The islands are overused because they are favored winter locations and of small area. They form a very small part of the total winter range area now occupied by muskox. The major part of the winter range is composed of wet tundra and beach grass-forb types, which will sustain a higher level of use. *Elymus* stands in particular are well suited to winter use since little or no use is made of them in the summer. When used in winter, the subterranean rootstocks and rhizomes protect the plants from damage. Evidence of heavy use was found on the landward sides of the Oongalambingoi Dunes and the Nunathloogagamiutbingoi Dunes, where *Empetrum*, *Betula nana exilis*, and *Arctostaphylos alpina* occur. These areas do not recover from use rapidly, and it appeared that once the vegetative cover was badly disrupted, loss of organic matter and associated nutrients and moisture capacities resulted in severe retrogression of vegetation.

Figure 6. Effects of muskox winter overuse of small island north of Atahgo Point (July 2, 1966).

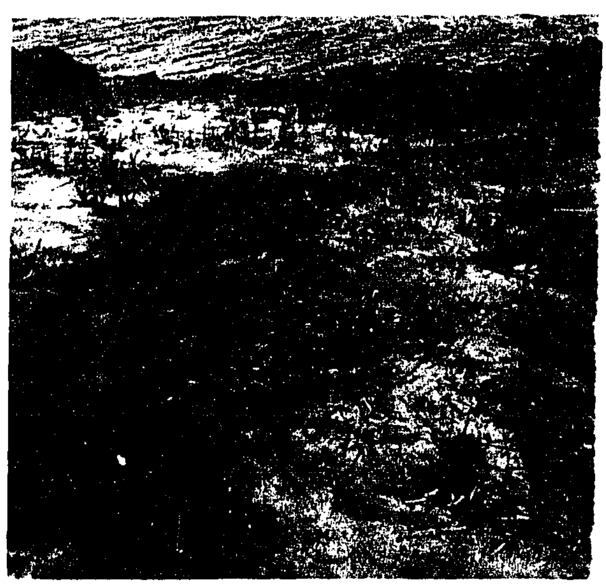


Figure 7. Portion of area shown in Figure 6. Elymus mollis shoots have grown from rhizomes and form the only vegetation on the site.

REINDEER

POPULATION GROWTH.

The Nunivak Island range has had a long history of use by herbivores. Caribou were once present, but information on their abundance and disappearance is largely lacking. Palmer (1938) credits Dr. E. W. Nelson with a caribou population estimate of 25,000 before disappearance, and a last record of caribou tracks in 1902. Reasons for the disappearance of caribou were listed as 1) overstocking of caribou and the eating out of lichens; 2) crusting of ice in severe winters; and 3) overhunting by Eskimos from Norton Sound and St. Michaels regions (Palmer 1936 Field Diary, L. J. Palmer Collection, University of Alaska).

Reindeer were introduced to the island in 1920 when 72 females and nine males were imported. In 1928, an additional 523 females were introduced (Palmer 1938). Also, in 1925, 10 woodland caribou (termed woodland caribou by Palmer) were placed on the island for crossbreeding purposes.

Following the 1920 introduction, the herd made rapid gains. In 1923, when the first reindeer corrals were built on the island, 223 reindeer were handled, and an estimate of the total herd was made at about 310 animals (Palmer 1923 Field Diary, L. J. Palmer Collection, University of Alaska). In 1925, there were 578 reindeer (Palmer 1938). Good records of Nunivak reindeer numbers were never kept after the introduction, and even in recent years population levels have only been guessed at. Table 7 lists the available estimates of the reindeer populations since introduction. The reliability of these estimates can be questioned, but the figures do give an indication of population trends. The herd increased rapidly after introduction, reaching peak numbers around 1944 and then showed marked declines until the early 1950's, after which it began increasing again. The population reached a second peak in 1964 and is possibly declining again.

The herd has been harvested since the 1920's. During the past decade, about 2,000 reindeer have been slaughtered annually. The size of the reindeer harvest has not been regulated with the objective of managing the herd at a desired level, but rather has been governed by the capacity of the slaughtering facilities and the general efficiency of the slaughtering operation. The harvest has generally not been sufficient to offset natural increases during times of herd growth. The only other population regulation factor has been food availability. The population trends indicated in Table 7 probably reflect trends in winter range condition.

<u>RANGE USE</u>.

During summer reindeer aggregate into large herds. A few groups of a dozen or less are seen, but the major part of the population is found in herds of several hundred to several thousand in number. Summer movements are extensive, with herds traveling as much as 20-40 miles daily. Reindeer movements are strongly influenced by weather, with reindeer usually going upwind. Reindeer are particularly restless on hot, windless days.

In summer reindeer occupy southcentral and western areas of the island. Those areas near to, and west of, Nash Harbor consistently receive heavy summer use. Reindeer are usually sighted in these areas during the annual July muskox aerial surveys. Tracks and droppings were often seen in western dry tundra regions, and reindeer trails were common in wet tundra areas.

Summer use is concentrated on sedges and grasses and on new browse growth where encountered. Prostrate willows are an important food which is sought in wet tundra areas. Willows along streams are taken, but the reindeer do not orient their feeding along stream valleys as do the muskox. Sedge and grass summer ranges are not limiting to reindeer; the summer growth of vegetation of this type is quite robust and exceeds the use made of it. The quality of these summer foods is high. Growing grasses and sedges make high levels of digestible protein available. *Carex aquatilis*, the dominant sedge of the wet tundra type, was found to be a high quality summer food by Skuncke (1967).

Table 7. Population estimates of reindeer on Nunivak Island 1920–1966.

Year	Population Estimate	Source
1920	81	Palmer 1938
1923	310	Palmer 1923 Field Diary
1925	578	Palmer 1938
1938	12,000	Palmer and Rouse 1945
1944	30,000	Palmer and Rouse 1945
1945	7,000	Palmer 1945 Field Diary
1948	7-10,000	USFWS 1964
1950	5,165	USFWS Files, Bethel, Alaska
1951	5,000	USFWS 1964
1953	3,000	USFWS Files, Bethel, Alaska
1956	4,900	USFWS 1964
1957	7,000	USFWS 1964
1958	8-10,000	USFWS 1964
1959	12,000	USFWS 1964
1960	14,332	USFWS 1964
1962	12,000	USFWS 1964
1964	15,500	USFWS 1964
1965	10,000	USBIA verbal comm.
1966	8,000	USBIA verbal comm.

Although grazing is not normally damaging to the range in summer, trampling can have a much more harmful effect, particularly when large numbers of reindeer are involved. Lichens are especially susceptible to fracturing in summer. Damage to lichens can have important consequences on winter ranges. Compaction of moist soil is another harmful result of trampling. On Nunivak Island the greatest apparent damage by trampling occurs when movements of large herds are interrupted by the sea cliffs on the western end of the island. The herds move into the wind on clear warm days, and upon reaching the cliffs begin to move in a tight circle. Vegetation is destroyed at such sites. On wet tundra areas the vegetation is churned into the peaty substratum (Fig. 8). One such location examined was undergoing rapid erosion (Fig. 9). Recovery of the vegetation on trampled areas takes many years. When such trampling occurs on dry tundra, the effects may be even longer-lasting. One such area near Dooksook Lagoon had the appearance of an erosion pavement with very little vegetation present (Figs. 10 & 11). Numerous trampled sites were found along the sea bluffs from Nash Harbor to Dahloongamiut Lagoon. It appeared that trampling has occurred in many recent years as areas in various stages of recovery were found. Aerial photographs taken in 1951 showed some trampled areas.

The pattern of reindeer use changes with the advent of winter. Reindeer winter primarily in the central and southcentral portions of the island, although scattered groups can be found from Nash Harbor to Cape Corwin. The reindeer occur in small scattered groups or in large widely dispersed herds, rather than the closer-knit, large

Figure 8. Effects of reindeer trampling on bluff near Nash Harbor (June 7, 1966).

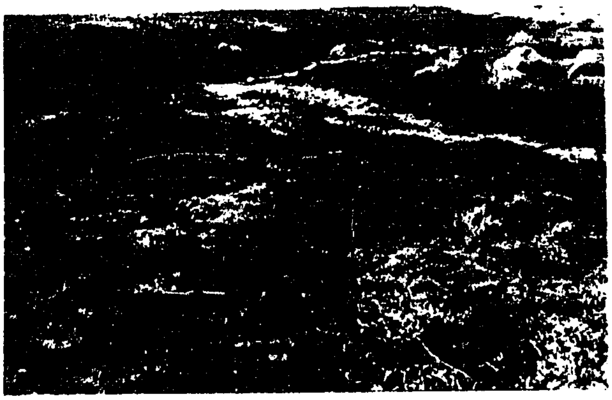


Figure 9. Erosion of a reindeer trampled site (June 10, 1966).

Figure 10. Effects of reindeer trampling on dry tundra type near Dooksook Lagoon (June 18, 1966).

Figure 11. Detail of erosion pavement shown in Figure 10.

concentrations of summer. Reindeer also tend to be more sedentary in winter. Although the herds are in constant movement, the extent of movement is much reduced from that of summer. Reindeer use is evident over much of the tundra. Droppings were found in many places and were especially abundant in overgrazed areas examined in summer. Invasion by Astragalus umbellatus was noted in overgrazed dry tundra areas near Duchikmiut. Curiously, the Cape Mendenhall area which lies just to the south has received little reindeer use in recent winters, although it has some of the only lichen range to be found on the island.

The Twin Mountain area has received heavy use in recent winters, probably because it is one of the few areas on the island with lichens. The Vaccinium uliginosum, Betula nana exilis, and Ledum decumbens in this area have been utilized heavily. Disruption of the vegetative cover occurred between visits to the mountain in 1965 and 1966. Hardest hit areas were on the ridges where winds had blown snow off the vegetation, making it available to reindeer. The alpine tundra receives heavy use in winter on many of the interior highlands and has reverted to an Empetrum-Carex association in some areas as a consequence. Ingriruk Hill, on the south side of the island, also showed considerable use. Reindeer remains, patches of bare ground, and abundant pellet groups attest to the use received by the area. Although lichens and browse are the preferred forage in winter, observations in March, 1966, indicated reindeer were utilizing the wet tundra species for feed.

The character of the vegetation on Nunivak Island has changed considerably since the time of reindeer introduction. Palmer (1923 Field

Diary) reported gathering 112 gunnysacks of lichens in 2 days. Later during the 1920's, in describing the vegetation on his successional study quadrats, lichens were reported to compose 80% of the total vegetative cover of the tundra lichen type and 30% of the wet tundra sedge-lichen type (Palmer and Rouse 1945). The present study indicated that lichens now form only about 12% of the dry tundra vegetative cover and are present in only trace amounts in wet tundra areas. Drastic changes due to reindeer overgrazing were evident to Palmer in 1944 when he wrote "Cape Etolin range entirely eaten off as to lichens from reindeer hills to Cape" (Palmer 1944 Field Diary). He also recommended not rounding up reindeer in the Nash Harbor area so as to conserve the lichen growth that remained there. He pointed out that high losses of reindeer occurred on Nunivak when reindeer were permitted to winter in depleted winter range areas, especially when crusting of snow occurred. At that time the reindeer tended to graze the east end of the island toward Mekoryuk.

The present study has indicated a distinct sparsity of lichens on the island, especially on the western portion of the island. Lichens were almost non-existent in the wet tundra type with the exception of lichen growth on peat mounds. On dry tundra, lichens were relatively unimportant cover components except in some southern and southeastern areas of the island.

Reindeer use has shifted in intensity from area to area in the past. Heavy use has usually been made of interior uplands where vegetation is available on windblown hills. During the past few years, Twin Mountain has received heavy use. During the winter of 1965-66, vegetative cover was broken by grazing and pawing in many places on the mountain, leaving numerous small patches of bare ground (Fig. 12). This area was also one of the sites of reindeer winter mortality following the 1964 high population levels. Examination of 21 remains in 1965 showed the majority were young animals less than 3 years old (Table 8). This type of mortality suggests that lack of food was the primary cause of death.

Table 8. Age and sex of winter-killed reindeer in the Twin Mountain area.

Age	Male	Female
½ yr.	2	1
1½ yr.	3	5
2½ yr.	5	2
3+ yr.	2	1

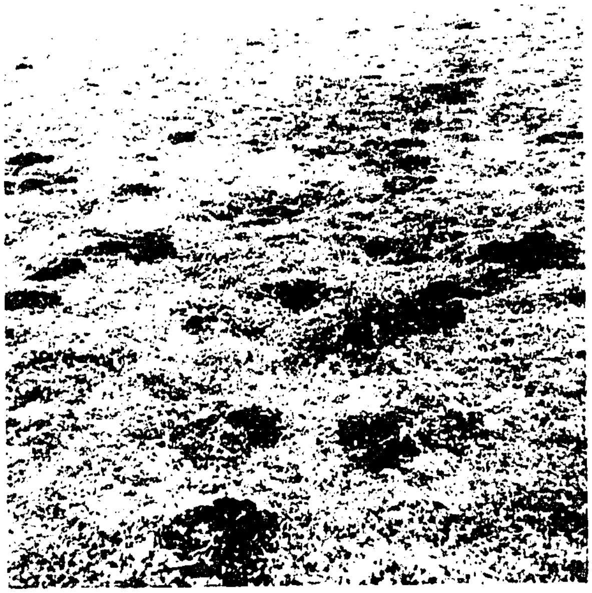


Figure 12. Effects of heavy reindeer winter use of alpine tundra on Twin Mountain. Bare ground scars are the result of pawing and grazing by reindeer (July 7, 1966).

MUSKOX-REINDEER INTERRELATIONSHIPS

RANGE AND POPULATION.

The management of the muskox herd on Nunivak Island should bear upon the relationship of the muskox to their range. This in turn is related to the reindeer use of the Nunivak range. The basic objective is that of keeping the muskox population at or below levels compatible with the carrying capacity of the range. The determination of these levels is a complex problem which will need to be solved, in part at least, through analysis of changing range relationships of the muskox as the range dependencies of an increasing population change. The role of the reindeer population needs similar consideration.

The character of the Nunivak range has been altered by overuse by reindeer to the point that lichen ranges are no longer present on the island. In fact, lichens are now only a relatively insignificant component of the vegetation. The greatest damage to the range occurred in the mid-1940's when the reindeer population reached its highest levels (Rouse 1948). Subsequent declines in reindeer populations suggest reduced grazing capacities. Partial recovery of the range (probably browse and sedge-grass range) in the early 1950's resulted in a second population increase, though of lesser proportions, which reached its peak in 1964. Current estimates of reindeer numbers and my field studies suggest that the reindeer population is again declining, with a continuation of poor range conditions and further range deterioration in some areas.

The effects of reindeer overuse of range upon the muskox are unknown. Up to the present time, effects of reindeer on the range have probably not been harmful to the muskox since muskox use vegetation characteristic of lower seral stages than reindeer, at least on Nunivak winter ranges. However, with the loss of lichen ranges on the island, the reindeer have come to depend on much the same type of winter forage as that which supports muskox. Occupation of the same winter range by both species would result in competition. Winter ranges examined in March, 1966, were separate for the two species. Muskox were concentrated along the coast while reindeer were scattered over much of the interior. No reindeer were seen feeding on muskox winter ranges. King (USFWS Files, Bethel, Alaska) reported seeing no evidence that the reindeer were using the dune grass or were in competition with muskox for food. This has not always been the case, however. Evidence of past winter use of sand dune areas by reindeer was found in the form of old shed antlers and skeletons. Such remains were found in most sand dune areas on the south side of the island and indicate that this important muskox winter range can be used by reindeer, probably during periods of high reindeer populations. At the time when this reindeer use of dune areas occurred, the muskox population was much lower. Competition, if it occurred, was probably not serious. Now that the muskox population is larger and increasing rapidly, future use of the beach type by reindeer could result in serious competition.

In the event of dual use of a range, efficiency of forage utilization could be a factor in determining differential survival.

Palmer (1944), using native browses, grasses, sedges, forbs, and lichens, noted that muskox appeared to utilize feed more efficiently than reindeer or caribou. If muskox are the more successful competitors, this ability would help to offset the limitation of being restricted to small winter ranges as the muskox on Nunivak appear to be.

Some of the muskox winter range on the northwestern bluffs has been affected by reindeer trampling in summer. The principal vegetation type affected is the wet tundra Carex-Eriophorum vegetation. In summer muskox use the trampled sites, grazing on the new green growth of the sedges and grasses which are revegetating the areas; they thus contribute to the slowness of recovery of these sites.

It is only in recent years that the muskox population has reached a size which warrants consideration of its impact on the range. Whereas reindeer have used most of the island during the winter, the muskox have always concentrated their winter use on a relatively narrow coastal fringe. Occupied muskox winter range has not increased proportionately with the growth in the muskox population. Whether or not muskox will accept interior areas as winter range when further population expansion occurs is not known. At present, Muskox Mountain has been the only interior area used as winter range by muskox for any period of time. Some herds are occasionally seen in interior areas in winter, but it is not known how long they remain there. Richard Davis, a native of the island, said that in past years some muskox have been seen on the southwestern side of Roberts Mountain and near Seemalik Butte in winter. If muskox do not accept new winter range, increased populations on the limited winter range now occupied may result in serious intraspecific competition. Favored winter locations receiving heavy use now will probably be overused regardless of whether expansion of the winter range occurs.

Summer ranges are also different for the two species. Muskox use primarily the grass-browse type in summer, while reindeer forage on wet tundra sedges and dry tundra browse species. The summer range has not been limiting to either species, nor is it likely that it ever will be. Both species utilize summer areas where rapid growth of vegetation more than compensates for forage utilized. Some slight competition may exist over shrub willows since both reindeer and muskox show preference for new willow growth.

RANGE CARRYING CAPACITY.

It is difficult to assess the degree of competition which may exist between muskox and reindeer without quantification of forage consumption and knowledge of forage preferences for the species involved. There has been no work done on forage requirements as related to carrying capacity for wild muskox. Some studies of spring and summer range use by captive muskox indicate muskox require .333 forage acres or 1.4 surface acres/head per month (Palmer and Rouse 1935). Palmer (1945) worked out range requirements for reindeer in Alaska. Spring, summer, and early fall requirements for reindeer were given as .462 forage acres or 1.386 surface acres/head per month, while late fall and winter requirements were .127 forage acres or .318 surface acres/head per month.

Several estimates of grazing capacity have been given for Nunivak Island. Rouse (1948) stated that a range examiner rated the grazing capacity at between 6,000 and 7,000 reindeer shortly after the island was set aside as a wildlife refuge in 1929. This estimate was made at a time when the range was in relatively good condition. Palmer (1938) judged the capacity at about 25,000 reindeer, or if reserving one-half of the range for muskox, at about 10,000 reindeer and 5,000 muskox (one muskox unit equals three reindeer units). These estimates were later revised to 2,100 muskox and 8,000 reindeer (Palmer and Rouse 1945). These requirements were based on yearly use of separate winter and summer ranges. For reindeer and muskox on Nunivak Island today, the winter capacity is the critical limiting factor since summer ranges are not thought to be limiting. Skuncke (1967), working on reindeer ecology in Sweden, found that the winter pasture determines the upper limit for the numbers of reindeer in the whole reindeer area. In the case of Nunivak Island, the reindeer winter and summer ranges are essentially the same, although more use is made of hills and mountains in winter.

Palmer (1945) believed reindeer grazing of winter lichen ranges should be based on a 50-year rotational pattern. Using a forage acre factor of .4, he determined a winter season requirement of 40.87 forage acres or about 95.4 surface acres/head per season, which allowed 6.7 reindeer to the square mile. If these figures are applied to Nunivak Island, a maximum carrying capacity of 11,629 is obtained. Approximately 4.5% of Nunivak Island is unavailable range in the form of barren rock or water, although in actuality this figure of unavailable range is probably closer to Palmer's (1945) estimate of 20% if inaccessible areas, swampy areas, and areas such as valley bottoms which are covered by deep snows are considered. If adjustments are made for these estimates of unavailable range, the reindeer grazing capacity is reduced to about 9,300 or 11,050 reindeer, depending on which estimate of unavailable range is used. However, these carrying capacity estimates are based on good reindeer range. The Nunivak range is in generally poor condition, and actual range capacities are probably much lower than 9,000 or 11,000 reindeer. These estimates also do not take into account muskox use.

Muskox use only a narrow coastal strip in winter. If the entire coast is considered (except for a small portion near Mekoryuk not used because of disturbance), the average width of the winter range probably does not exceed one-quarter mile. An estimate of the muskox winter range, based on 306 miles of coastline, is 48,960 acres. No data is available on winter range carrying capacities for muskox for comparison with reindeer use. Realizing the limitations involved, if Palmer and Rouse's (1935) estimate of muskox summer range requirements (1.4 surface acres/head per month) is applied to Nunivak winter ranges, the grazing capacity of the present muskox winter range would be about 5,830 muskox. Only a small portion of the winter range defined above is actually used now. Whether the entire area could or would be used is not known.

If the muskox winter range, not normally used by reindeer, is subtracted from the acreage available for reindeer, a combined carrying capacity of 5,830 muskox and 8,790 reindeer is obtained. These estimates are highly conjectural and are presented here only for purposes of approximation. To determine carrying capacities for reindeer and muskox on Nunivak Island, studies are needed to determine forage preferences of each species, allowable use for the different forage species, cover and composition percentages of forage species, extent of the areas used as winter range by both species, and range condition and trend. Effects of competition, if a factor, would serve to complicate the problem.

The situation on Nunivak Island with respect to the muskox and reindeer is an unnatural one. Both species have been introduced to the island and are confined to it by the surrounding sea. This confinement results in a more critical limit to the island's carrying capacity since there is no emmigration. Harvest of reindeer by man has been limited and ineffectual in controlling population levels. Lack of predators on the island has resulted in regulation of populations by food availability. This is characteristically an unstable situation, especially in the Arctic where plant associations are easily disrupted and slow to recover. The vegetation of the island has been altered by overuse, resulting in lowered carrying capacities. It can be expected that range overuse will continue until the reindeer herd is reduced and held at levels which will allow recovery of the range. Overuse by muskox and competition with reindeer may become increasingly important problems.

ADMINISTRATION.

Nunivak Island is a national wildlife refuge administered by the USFWS. At the present time, it provides the habitat for the only wild muskox herd in the United States. One of the primary objectives in the administration of the refuge is the maintenance of the welfare of the muskox, which entails maintenance of the range as well. Transplantation of muskox to other ranges in Alaska and hunting of the species will be the main controls used on the population. The reindeer herd is owned by the federal government and managed by the U.S. Bureau of Indian Affairs. Up to the present time, management of the reindeer herd has been concerned with providing a harvest and not with maintaining the herd at levels required for the improvement of the range. The range is the responsibility of the USFWS, not only as it pertains to use by muskox and reindeer, but also as it provides a flora of definite scientific value. The USBIA has responsibilities toward the Eskimo population on the island whose well-being is determined in large part by the local reindeer industry. The situation is not one which necessitates conflicting uses. The responsibilities of both agencies can be realized and a meaningful management program for both muskox and reindeer can be initiated if closer cooperation between the agencies can be effected. The reindeer population could be maintained at levels which would allow for reindeer harvests of a size comparable to harvests in recent years, or possibly higher, and still be commensurate with range rehabilitation objectives. The muskox on the island were originally intended to serve as a reservoir for transplants to former ranges in Alaska, and presumably this objective is still foremost. It is not necessary that the muskox population reach carrying capacity levels to achieve this objective, so that range overuse by muskox need not complicate the situation. If transplant removals cannot serve to hold the population in check, hunting can be used to control population growth.

APPENDIX A Nunivak Island Plant Species Collected in 1965 and 1966.

DIVISION LEPIDOPHYTA

Lycopodiaceae

Lycopodium alpinum L.
L. selago L.

DIVISION CALAMOPHYTA

Equisetaceae

Equisetum arvense L.
E. pratense Ehrh.
E. sylvaticum L.

DIVISION PTEROPHYTA

Aspidiaceae

Cystopteris fragilis (L.) Bernh.
Dryopteris oreopteris (Ehrh.) Maxon.

DIVISION ANTHOPHYTA

Betulaceae

Betula nana L. ssp. *exilis* (Sukatch.) Hult.

Boraginaceae

Mertensia maritima (L.) S.F. Gray

Campanulaceae

Campanula lasiocarpa Cham.

Caryophyllaceae

Arenaria obtusifolia (Rydb.) Fern.
A. peploides L.
Lychnis apetala L.
Silene acaulis L.
Stellaria humifusa Rottb.
S. ruscifolia Pall. ssp. *aleutica* Hult.
S. sitchana Steud.

Compositae

Achillea borealis Bong.
Antennaria monocephala DC.
A. pygmaea Fern.
Arnica lessingii (T. & G.) Greene.

APPENDIX A (Continued)

Artemisia arctica Less. var. beringensis Hult.
A. glomerata Ledeb.
A. laciniata Willd.
Chrysanthemum arcticum L.
Hieracium triste Cham.
Petasites frigidus (L.) Fries.
Saussurea angustifolia (Willd.) DC.
Senecio congestus (R.Br.) DC. var. palustris (L.) Fern.
S. fuscatus (Jord. & Fourr.) Hayek.
S. pseudo-arnica Less.
S. resedifolius Less.
Solidago multiradiata Ait.

Convallariaceae
Streptopus amplexifolius (L.) DC.

Cornaceae
Cornus suecida L.

Crassulaceae
Sedum roseum (L.) Scop.

Cruciferae
Arabis divericarpa A. Nels.
Cardamine pratensis L.
Cochlearia officinalis L.
Draba nivalis Lilj.
Parrya nudicaulis (L.) Regel.

Cyperaceae
Carex aquatilis Wahl.
C. atrata L.
C. bigelowii Torr.
C. capillaris L.
C. glareosa Wahl.
C. macrochaeta C.A. Mey.
C. nardina Fr.
C. physocarpa Presl.
C. podocarpa R.Br.
C. stylosa C.A. Mey.
Eriophorum angustifolium Roth.
E. chamissonis C.A. Mey.
E. scheuchzeri Hoppe.

Diapensiaceae
Diapensia lapponica L. ssp. obovata (F. Schmidt.) Hult.

APPENDIX A (Continued)

Empetraceae
Empetrum nigrum L.

Ericaceae
Andromeda polifolia L.
Arctostaphylos alpina (L.) Spreng.
Ledum decumbens (Ait.) Lodd.
Loiseleuria procumbens (L.) Desv.
Vaccinium uliginosum L.
V. vitis-idaea L.

Fumariaceae
Corydalis pauciflora (Steph.) Pers.

Gentianaceae
Gentiana albida Pall.
G. glauca Pall.

Geraniaceae
Geranium erianthum DC.

Graminae
Agrostis aequivalvis Trin.
A. borealis Hartm.
Alopecurus alpinus J.E. Sm.
Arctagrostis latifolia (R.Br.) Griseb.
var. *arundinaceae* (Trin.) Griseb.
A. poaeoides Nash.
Calamagrostis canadensis (Michx.) Beauv.
C. deschampsiodes Trin.
Colpodium fulvum (Trin.) Griseb.
Deschampsia caespitosa (L.) Beauv.
Elymus mollis Trin.
Festuca altaica Trin.
F. brachyphylla Schult.
F. rubra L.
Hierochloe alpina (Sw.) Roem. & Schult.
H. odorata (L.) Beauv.
H. pauciflora R.Br.
Phippsia algida (Soland.) R.Br.
Poa arctica R.Br.
P. eminens Presl.
P. pratensis L.
Puccinellia phryganodes (Trin.) Scribn. & Merr.
Trisetum sibiricum Rupr.

APPENDIX A (Continued)

Haloragidaceae
Hippuris vulgaris L.

Iridaceae
Iris setosa Pall.

Juncaceae
Juncus arcticus Willd.
J. balticus Willd.
J. biglumis L.
Luzula confusa Lindeb.
L. multiflora (Retz.) Lej.
L. nivalis (Laest.) Beurl.
L. parviflora (Ehrh.) Desv.
L. wahlenbergii Rupr.

Leguminosae
Astragalus alpinus L.
A. umbellatus Bunge.
Lathyrus maritimus (L.) Bigel.
Oxytropis nigrescens (Pall.) Fisch.

Liliaceae
Lloydia serotina (L.) Wats.

Melanthaceae
Tofieldia coccinea Richards.

Onagraceae
Epilobium anagallidifolium Lam.
E. angustifolium L.
E. latifolium L.

Orchidaceae
Listera cordata (L.) R.Br.
Orchis rotundifolia Pursh.

Papaveraceae
Papaver radicum Willd.

Polemoniaceae
Polemonium acutiflorum Willd.

Polygonaceae
Oxyria digyna (L.) Hill.
Polygonum viviparum L.
Rumex arcticus Trautv.

APPENDIX A (Continued)

Portulacaceae
- *Claytonia sarmentosa* C.A. Mey.

Primulaceae
- *Androsace chamaejasme* Host. ssp. *lehmanniana* (Spreng.) Hult.
- *Primula cuneifolia* Ledeb.
- *P. egalikensis* Wormskj.
- *P. tschuktschorum* Kjelln.
- *Trientalis europea* L.

Pyrolaceae
- *Pyrola minor* L.

Ranunculaceae
- *Aconitum delphinifolium* DC.
- *Anemone narcissiflora* L.
- *A. richardsonii* Hook.
- *Caltha palustris* L. var. *arctica* (R.Br.) Huth.
- *Ranunculus nivalis* L.
- *R. pallasii* Schlecht.
- *R. pygmaeus* Wahl.

Rosaceae
- *Dryas octopetala* L.
- *Potentilla pacifica* Howell.
- *P. palustris* (L.) Scop.
- *P. pennsylvanica* L. var. *glabrata* Wats.
- *P. villosa* Pall.
- *Rubus arcticus* L.
- *R. chamaemorus* L.
- *R. stellatus* Smith.
- *Sanguisorba sitchensis* C.A. Mey.
- *Spirea beauverdiana* Schneid.

Salicaceae
- *Salix alaxensis* Cov.
- *S. arctica* Pall.
- *S. ovalifolia* Trautv.
- *S. polaris* Wahl. ssp. *pseudopolaris* (Flod.) Hult.
- *S. pulchra* Cham.
- *S. reticulata* L.

Saxifragaceae
- *Chrysoplenium wrightii* Franch. & Sav.
- *Parnassia palustris* L.
- *Saxifraga bracteata* D. Don.

APPENDIX A (Continued)

S. bronchialis L. ssp. *funstonii* (Small.) Hult.
S. cernua L.
S. hieracifolia Wallst. & Kit.
S. punctata L. ssp. *insularis* Hult.
S. rivularis L.

Scrophulariaceae
Lagotis glauca Gaertn.
Pedicularis lanata Willd.
P. langsdorfii Fisch.
P. oederi Vahl.
P. penelli Hult.
P. verticillata L.

Sparganiaceae
Sparganium hyperboreum Laest.

Umbelliferae
Angelica lucida L.
Cnidium ajanense (Reg. & Tiling.) Drude.
Conioselinum benthami (Wats.) Fern.
Ligusticum hultenii Fern.
L. multellinoides (Crantz.) Willar.
ssp. *alpinum* (Ledeb.) Thellung.

Valerianaceae
Valeriana capitata Pall.

Violaceae
Viola langsdorfii Fisch.

APPENDIX B   Muskox Population Composition Counts – 1965 and 1966.

Date of Observation	Calves	Yearlings	Subadults	Cows	Bulls	Totals
7/17/65	8	4	4	9	2	27
7/19/65	4	3	2	5		14
7/22-25/65	3	4		3	1	11
		1	2	2	1	6
	2		2	2	1	7
	2			3	1	6
	1			2	2	5
	3	1		3	1	8
		3	2			5
	2			2	1	5
	2		1	2	1	6
	2	2		2	1	7
	1		2	1	1	5
	1	3	1	1	1	7
	2			2	1	5
8/10/65	1	1		2		4
8/11/65	1	1		2	1	5
8/15/65	2	4		2	1	9
8/26/65	2		2	3	1	8
	3			3	1	7
	3	4	1	4	1	13
	2			2	1	5
	2		1	2	1	6
	1	2		2	1	6
	2		1	2	1	6
	3	1		3	1	8
6/7-7/7/66	4		3	5	3	15
	1	2	3	1		7
	2	1		2		5
	3	1	2	3	3	12
					1	1
					1	1
	2	4		3	3	12
	1	2		2	1	6
					5	5
					1	1
					2	2

APPENDIX B (Continued)

Date of Observation	Calves	Yearlings	Subadults	Cows	Bulls	Totals
6/7-7/7/66	4	4	1	5	3	17
					1	1
	3	1	5	4	1	14
	2	3		2		7
					4	4
	3	3	4	3	3	16
	7	5	3	8	1	24
	2	4		2		8
					1	1
					2	2
					1	1
					2	2
					2	2
				1		1
7/15-7/16/66	2	1		2	1	6
					2	2
					1	1
	4			4	1	9
					1	1
					1	1
					1	1
					1	1
					2	2
	2		1	2	1	6
	1			3	1	5
	2			3	1	6
			2		3	5
					1	1
	2			3	2	7
	2		1	2	1	6
7/20/66	2		1	2	1	6
8/10-8/11/66					1	1
	1	3		3	1	8
8/15/66	2	1		2	1	6
	1	3	1	2	1	8
					1	1
					2	2
					1	1
					1	1
					1	1
					2	2

APPENDIX B (Continued)

Date of Observation	Calves	Yearlings	Subadults	Cows	Bulls	Totals
8/15/66					1	1
					1	1
	3	3	1	4	1	12
	2	2	1	3	1	9
					1	1
	2	4		3	1	10
					1	1
					1	1
					2	2
	1	4	3	1	1	10
					1	1
	4	1		3	1	9
					1	1
	4		1	4	1	10
					1	1
				1		1
1965 Totals	57	36	23	69	26	211
1966 Totals	71	56	35	84	89	336

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